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THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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A MICRO HARDNESS TESTING MACHINE

By HEINRICH HANEMANN. (From *Zeitschrift fur Metallkunde*, Vol. 32, No. 2, February, 1940, pages 35-38).

HARDNESS testing by Brinell, Rockwell and Vickers methods affects a larger number of crystals. This means that not only the crystalline plastic deformation, but also distribution, magnitude, quantity, etc., of the crystals are influencing the result.

So far, microscopic hardness measuring methods have not been adopted, apart from the examination of scratch hardness and abrasive hardness. The last two methods, however, measure rather the resistance to wear than the plastic deformation. A new method developed by E. M. Lips is based on microscopic measurement of plastic deformation. The results are expressed in the same units as the standard hardness numbers, and hence are comparable within certain limitations.

Micro hardness testing can be split up into several stages: (a) location of the exact point where examination is to take place (b) impression, and finally (c) measurement of impression. (a) and (c) require an optical instrument, while (b) necessitates a mechanical arrangement. Both these can be designed with an interchanging device, to bring the optical axis of the instruments into the same line in turn. But when it comes to hardness testing of individual crystals with dimensions of only a few μ, the accuracy of the mechanical device is very insufficient.

The new micro hardness testing device eliminates the interchanging mechanism by unifying the indentor with the lens. One solution of the problem was apparent: to grind the pyramid-shaped indentor on the face of the lens nearest to the test sample. In order to neutralize the di-optical effect of the pyramid, the instrument should be used in conjunction with a homogeneous immersion fluid.

Difficulty was experienced with the choice of lens material and immersion fluid of the same refractive index. The lens should be of great hardness (such as diamond), but no immersion fluid is known to have the same refractive index. Finally, fused quartz was selected for the lens material and glycerine for the immersion fluid. The dispersion of quartz and that of glycerine differ, however, hence, monochromatic light was used with a wave-length of 5461 A, no chromatic correction being made.

The limitation of this arrangement to the hardness measurement of softer crystals was an inducement to investigate the possibility of attaching a diamond pyramid to the objective lens.

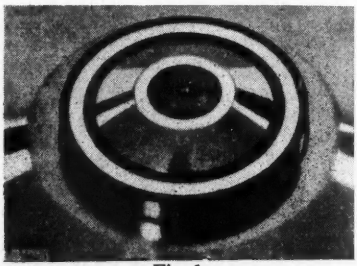


Fig. 1

As shown in Fig. 1, a diamond pyramid, when fixed to a lens, leaves a ring-shaped part of the lens free for illumination and inspection of the test sample. Part of the light beam, entering the lens through a small angle of aperture, is cut out. An 8 mm. apochromatic objective of 0.65 numerical aperture was used, of which the front lens had a diam. of 2.3 mm. The diamond was of 0.8 mm. diam.

This optical arrangement is fixed to a mechanical device for measuring the loading (Fig. 2). Ring-shaped springs are used to take up the lens, since the loads transmitted are very small (0.2 to 100 g.), and the friction of the load transmitting mechanism should be as small as possible. The magnitude of the deflection of these springs is a measure of the test load. An auxiliary objective is introduced (e in Fig. 2) between the objective and the vertical illuminator. This auxiliary objective occupies that part of the beam which is useless for examination due to the presence of the diamond pyramid. The auxiliary lens,

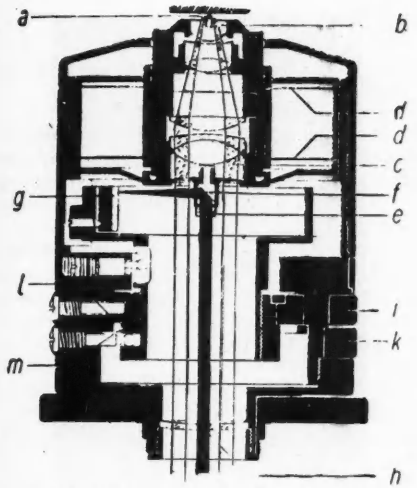


Fig. 2. Schematic cross section of the Micro Hardness Testing machine Type Zeiss D.30. (a) Diamond pyramid ; (b) Front lens ; (c) Eyepiece ; (d) Ring-shaped springs ; (e) Auxiliary objective ; (f) Mirror ; (g) Scale for test load ; (h) Correcting lens ; (i, k) Graticule discs ; (l) Eccentric for fine adjustment ; (m) Spindle for zero adjustment.

together with a mirror at 45° (f), serves to illuminate a scale (g) fixed to the casing of the instrument. The test load on the objective causes bending of the disc springs and shifts the auxiliary lens by the same amount along the line of light beam. The scale is adjustable in every direction, hence, the possibility of a zero adjustment.

A special eyepiece was designed for measuring the impression, fitted with a micrometer spindle and two graticule discs rotating in opposition to each other. Two angular locating marks are arranged so that in the zero position of the microscope they form a cross, and in any other pos tion they form a square of measurable dimensions. Since the eyepiece is laterally adjustable in the tube, the cross position of the mark is used to mark the position of the impression. The mark is also used to take readings of the loading. The area of the impression can be determined if the angular marks are shifted by an amount equal to the side of the impression. If the impression is not square-shaped, it can be easily converted to a square of the same area.

Fig. 3 View of the instrument.
Type Zeiss D.30.

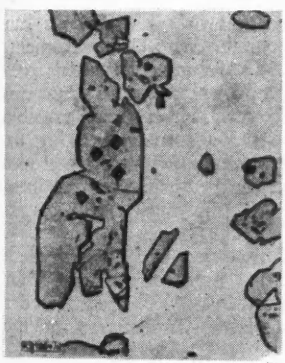


Fig. 4 400 : 1

Aluminium Alloy surrounded by 5% primary Cr crystals.
Test load 10g.
Hardness { Primary crystals 450 Kg/mm²
Peritectic 580 Kg/mm²

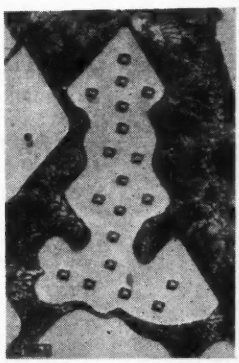


Fig. 5 700 : 1

Aluminium Alloy with 42% Cu. Primary crystals $Cu Al_2$ without coring.
Test load 5g.
Micro Hardness, 780 Kg/mm²

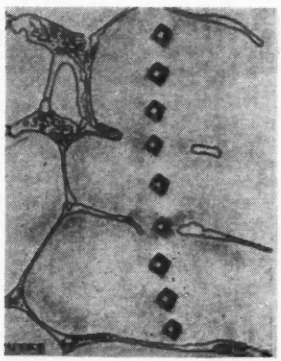


Fig. 6 400 : 1

Aluminium Alloy, with 6% Cu Primary Aluminium solid solution, with coring.
Testload 5g.
Micro Hardness 81 to 115 Kg/mm²

Fig. 7.

Eloxal layer on hydronalium. By treating the layer with water-glass, the original Aluminium hydroxide has changed to Sodium-Aluminium-Silicate.

Testload 20g. Micro Hardness in the eloxal layer 250-420 Kg/mm²

The instrument is very simple to handle. The surface of the sample is brought into focus and the sample so arranged that the crystal to be tested comes in the correct position. The objective is then lowered on to the specimen until the test load is reached. Measurement of the impression follows.

The manifold use of the instrument is illustrated in the following few examples.

In Fig. 4 the individual crystals of an aluminium alloy are identified by their respective hardness values. The primary crystals are softer than the peritectic region.

Equilibrium systems can be examined with the instrument by determining the passing into solution of individual constituents (Figs. 5 and 6).

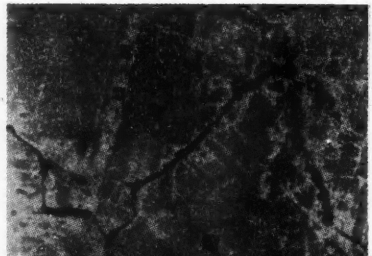


Fig. 8 400 : 1

Magnetite with Hemitite precipitation. Test load 50g.

Hardness { Magnetite 690 Kg/mm²
Hemitite 1100 Kg/mm²

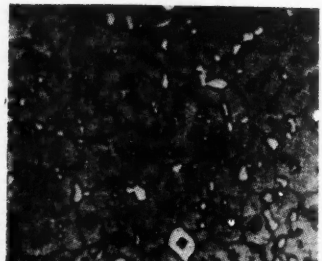


Fig. 9 850 : 1

High speed tool steel. Test load 5g.

Hardness { Carbide 3,300 Kg/mm²
Martensitic matrix 1,500 Kg/mm²

The variation of hardness in thin layers such as in electro-plating and nitride hardening can be determined. In Fig. 7 the hardness of a layer of eloxal is measured, and was found to be 250 kg/mm² on the surface and 420 kg/mm² in the inside.

Since the hardness of small crystals can be determined separately with this instrument, the hardness of solid solutions in which precipitation of a second phase has occurred can be measured, since it is almost always possible to find places free from the precipitate (Fig. 8).

In Fig. 9 the hardness of high speed tool steel is measured by measuring the hardness of the carbide and the martensitic matrix independently.

It was found that substances which were regarded as brittle could be examined for hardness if small test loads were used. Under such conditions plastic deformation of the substance resulted.

This method could be adopted to determine the hardness of minerals too. Even minerals like corundum and spinel showed plastic deformation. The method was extended to silica and kindred substances with very good results.

FUEL SUBSTITUTES FOR MOTOR VEHICLES

By Dipl. ING. MAX TROESCH. (From *Schweizerische Bauzeitung*, Vol. 116, No. 21, 23rd November, 1940, pp. 235-239)

"OTTO" motors were, so far, used only with petrol fuel, evaporated or injected into the combustion chamber and ignited by an electric spark. Hence fuel substitutes, too, should be evaporable, in order to avoid costly alterations on the engines. With liquid fuel substitutes the employment of a suitable evaporator gives an easy solution, but, with solid fuels, the problem is more difficult. For Diesel engines no liquid substitutes could be found so far to give satisfactory results, unless ignition plugs are used.

Solid fuel substitutes, such as wood gas, charcoal and carbide, can be easily gasified, but due to their low calorific value a drop in the output of the engine of the order of about 20 to 40% should be expected.

Wood gas is the most widely adopted fuel substitute. The wood fuel should consist of pieces about the size of the fist, with a water content not exceeding 10 to 15%.

Fig. 1 shows the schematic arrangement of an Imbert type of generator. Essentially it is a double walled cylinder of about 1800 mm. height and 530 mm. diam. The sequence of the treatment of the wood in the producer consists of drying, gasifying, oxidation and reduction. On the top of the cylinder the wood is dried first by the hot gases. The ensuing vapours are condensed and separated at a temperature of about 200° C. As the temperature is increasing to about 280° C. towards the bottom of the cylinder, carbonic acid, and acetic acid are liberated from the wood. In the following temperature range from 280° to 500° C., acetic acid, methylalcohol and tar are liberated. The wood is now almost completely dry, and free from gases, and is reaching the oxydation region in the hearth, where air is admitted through nozzles arranged around the periphery. The temperature is reaching about 1300° C. at this point. The carbonic acid combines with the carbon of the wood, and also with the carbon monoxide, which forms the main constituent of wood next to nitrogen. The composition of the resulting gas is approximately:

Gas	CO	H_2	CH_4	CO_2	O_2	N_2
Prop. by Vol. %	21	17	1.8	12	0.4	47.8

The generator is started by a fan, which draws air through the system, until the fire and hence the gas production is well in progress.

Wood gas can be used with higher com-

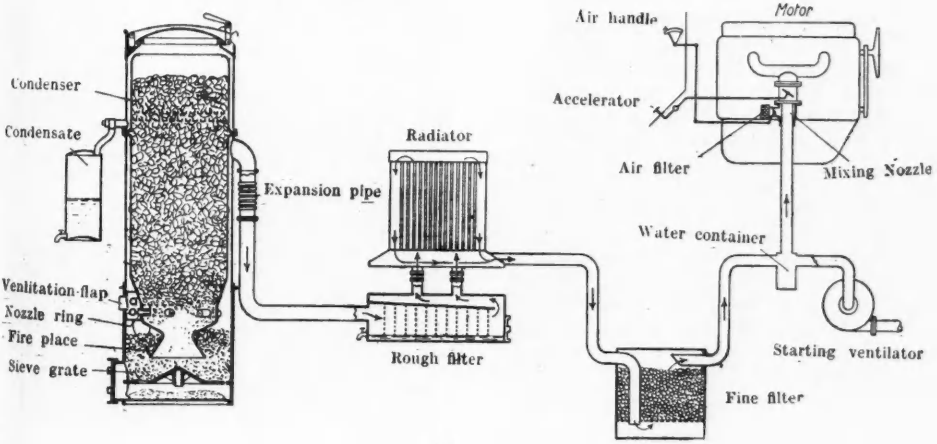


Fig. 1

pression ratios than petrol, hence the drop in the output, and efficiency can be partly neutralised by raising the ratio. Usually a compression ratio of about 1:8 is used, but with Diesel engines the compression ratio has to be reduced from 1:15 to 1:10, using sparking plugs, of course.

The economic advantages of wood gas are mainly due to the cheap cost of wood. For a given car with a fuel consumption of 11 litre/100 km. the wood consumption is about 2.5 kg/100 km. In Fig. 2 the fuel economy is illustrated graphically. The values are in Swiss franks (1 S. Fr. = 1 sh. approx.). The actual expenses are somewhat higher, due to the maintenance and amortization costs of the generator.

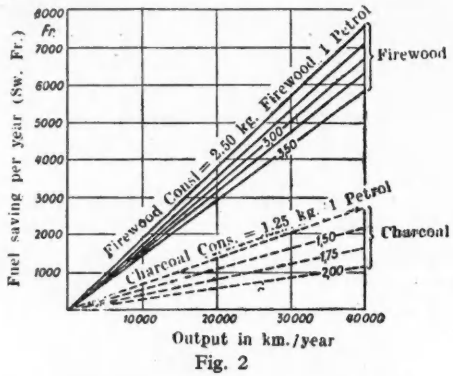


Fig. 2

Charcoal generators are very suitable for passenger cars, due to their smaller dimensions. The smoke generated is also less with these generators. The generators can be classified in three groups : (1) built on trailers ; (2) fitted in the car ; and (3) built in the luggage carrier of the car.

The HERA charcoal trailer (Fig. 3) is built on a welded tube frame, and is attached to the car by two pivots. On the rear of the tube frame a single pneumatic tyre is arranged. The front of the trailer carries the charcoal container (capacity about 60 kg.) below which is the fire place and the air nozzles. A rough filter is in front of the fire place, with an opening to the side to enable easy access for cleaning. The fine filter is fitted to the rear of the fuel container.

The compression ratio of the engine is not

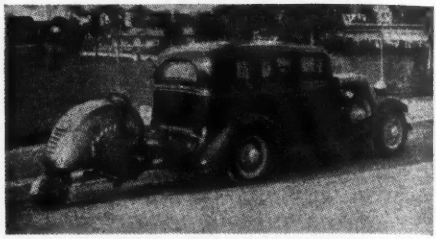


Fig. 3

altered. An intermediate connection is fitted between the evaporator and suction tube, and by means of two valves provided the motor can be changed over from petrol fuel to charcoal gas fuel, or vice versa, even while the motor is running. The motor can also run on mixed fuel (petrol and gas), which comes very useful when the motor is heavily loaded, as is the case on a mountain path.

The VOLVO generator (Fig. 4) is made almost completely from pressed sheet metal. The triangular frame is attached to the car by two ball joints. A novelty is the enlarged frame supports, which serve as cooler for the gas. The gas flowing from the generator to the rough filter and from here to the fine filter are passing through the frame supports and are cooled (Fig. 5). The capacity of the fuel container is about 70 kg.

The motor can be started, without using petrol by means of a fan, this, however, requires about 20 minutes, while if petrol is used for starting it only takes about 4 minutes.

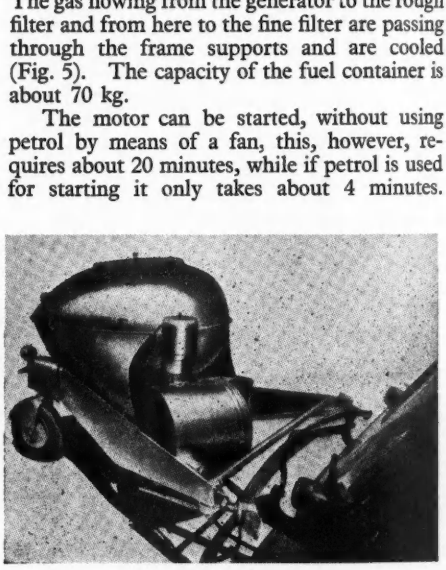


Fig. 4

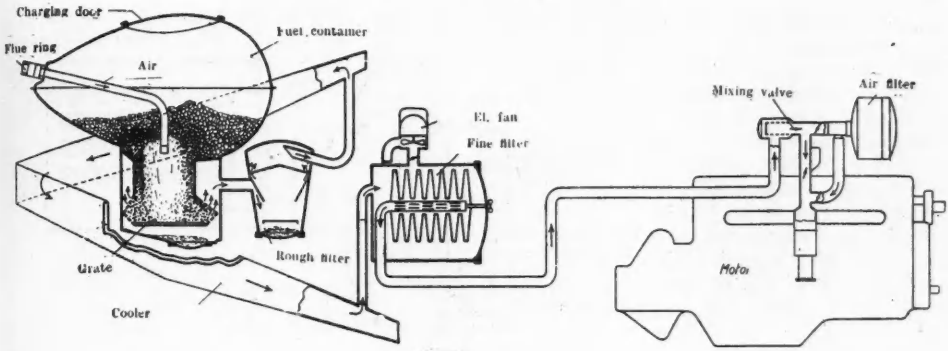


Fig. 5.

The temperature of the gas at various points in the system is as follows :

Before rough filter	400°C.
After rough filter	150°C.
Before fine filter	50°C.
After fine filter	30°C.

No separate cooler is needed for the air, as it is admitted through a cylindrical tube at the top of the container.

The generator was tested on a B.M.W., 10 h.p., 1939 type, 4-5 seater of 1600 kg. weight. The car was loaded with three passengers on the outward journey, and with five passengers on the return. The total distance covered was 274 km. The fuel consumption (deducting 0.9 kg. of ash) was 49.9 kg., i.e. 18 kg./100 km.

A similar type of generator with a larger fuel carrying capacity was designed and fitted to lorries (Fig. 6).

The FRANZ type generator is fitted in the luggage carrier of the car (Figs. 7 and 8). It consists of a fire brick lined furnace, with a transverse gasifier. Two nozzles, a light load and a full load nozzle, are fitted in the furnace, so that the passage of the air is transverse to the passage of the fuel. To increase the oxide production of the generator, arrangements are made to allow water vapour to reach the main jet. As in the previous cases a rough filter and a fine filter are employed. The cooler is fitted to the bottom of the undercarriage, and should be well protected from dust and dirt. The economical advantages of this system can be seen from Fig. 2. The calculations are based on a fuel consumption of 18 kg./100 km., with prices of 75 Rp./1 of petrol, and 30 Rp. per litre of charcoal. The cost of the generator set is between 1800-3500 Fr.

A third solid fuel substitute is carbide, produced in electric furnaces by burning lime. Lime is transformed to gaseous acetylene by the addition of water, thus :

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2.$$

The gases are either generated in the car or carried in bottles under pressure.

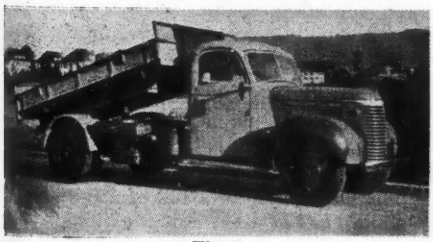


Fig. 6

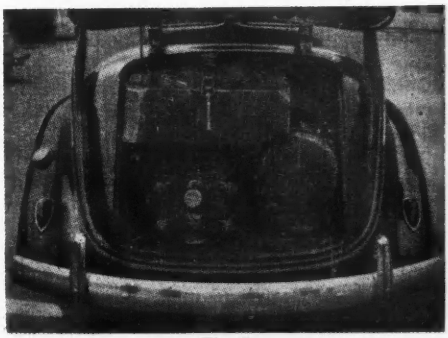


Fig. 7

Since carbide has a very low anti-knock value (Oct. No. 40) "dopes" must be used. Although reasonably satisfactory results are obtained with these, it cannot be used on a wide scale on account of the high prices of the "dopes." Carbide can also be used to produce liquid fuel, viz., polaldehyd, which has characteristics similar to those of alcohol, with a calorific value of 6000 WE/kg., and an Oct. No. over 100.

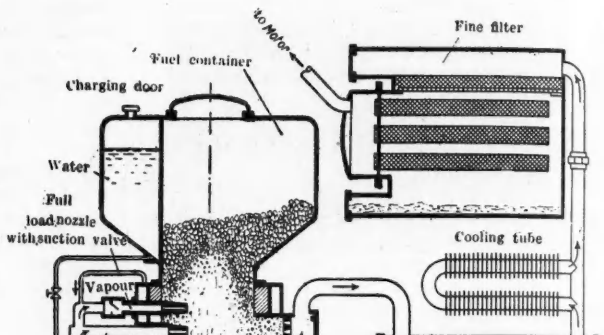


Fig. 8

WELDING OF CHILLED ROLLS

By DIPL. ING. K. HOFFMANN. (From *Die Giesserei*, Vol. 27, No. 8, April 19th, 1940, p. 148).

FRACTURING of the necks on cast iron rolls is the result of excessive torsional forces or bending moments. It occurs very frequently with chilled rolls, where due to the hardened surface the material is made especially sensitive to such forces. In the case of semi-hard rolls it is customary to replace the fractured neck by overflow welding. The roll is built in vertically in the floor with the broken surface to the top, and a mould is placed round the surface of fracture. The surface of fracture is carefully heated, then molten iron is allowed to flow on the surface from a height of about 1 m.

When unevenness can no longer be detected by means of a poker, the overflow of the mould is closed and a mould corresponding to the broken off neck is fixed to the roll and is filled up with molten iron.

The same method can be employed with chilled rolls. Practice has proved that this process is successful in most cases. As a matter of fact, the strength characteristics of the new neck are better than those of the original.

The great sensitivity of chilled rolls is due to the modern foundry methods of producing a hard outside surface with a soft centre. There are still a great number of chilled rolls in stock and many of these are fractured. It is very important to be able to repair them by welding on a neck with a strong transition part between the body and the neck.

Only a few additional precautions have to be taken in this case. The preliminary warming up must be carried out with great care. The remainder of the fracture up to about 25 mm. height must not be removed, as an uneven surface is more favourable for the welding purposes than a planed one.

Sometimes, during welding, the internal strains in the rolls are being released and consequently cracks occur. These are not necessarily in contact with the fractured surface and may be axial or transversal. The frequency of cracks appearing on the surface is about 4 to 8%. Naturally, such rolls are quire useless.

The success of welding is reduced if chromium carbides are present. Hence about 20 to 25 mm. depth of the fractured surface is welded before closing the draining tap hole.

As an illustration of the method the following example is quoted :

For the welding of a roll of 250-350 mm. diam., 800 to 1200 kg. of iron is required. 650 to 900 kg. of iron for overflow and 150 to 300

kg. welded-on iron. The welding requires about 10 to 15 minutes. For the overflow, grey iron is used, while the mould is filled after closing the overflow tap hole with better quality iron. The process is only economical if the overflow iron can be used for castings.

As a rule the output of such welded rolls more than pay the costs of welding.

NEW GERMAN MACHINE TOOLS

By KARL HAASE. (From *Werkstatt und Betrieb*, Vol. 73, No. 4, April, 1940, pp. 69-75).

COUNTERWEIGHT changing of gears (Figs. 1 and 2) prevents faulty and noisy changing of gears by employing a disc clutch. The lay-out lengths are increased, and so is the cost, compared with ordinary toothed gear changing, but the many advantages obtained more than compensate for these.

A straight-line automatic machine for chuck jobs up to work pieces of 200 mm. dia. and 180 mm. turning length is shown in Fig. 3. Eight groups of tools can work simultaneously on 4 work pieces. The main shaft is brought automatically to rest, if charging of the machine is not finished before the slide starts moving.

A new single-spindle semi-automatic machine for chuck jobs up to 150 mm. dia. (Fig. 4) is characterised by a cross shaped turret head, with four holes to take up the work, and a support for an external turning mechanism. The machine is fitted with a stepless PIV chain drive, and speeds from 95 to 1800 revs. per minute can be obtained.

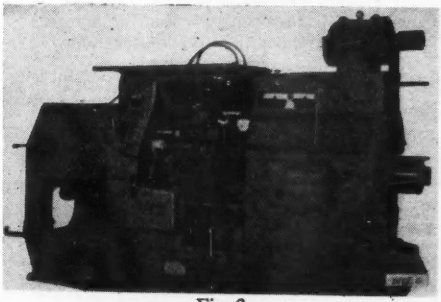
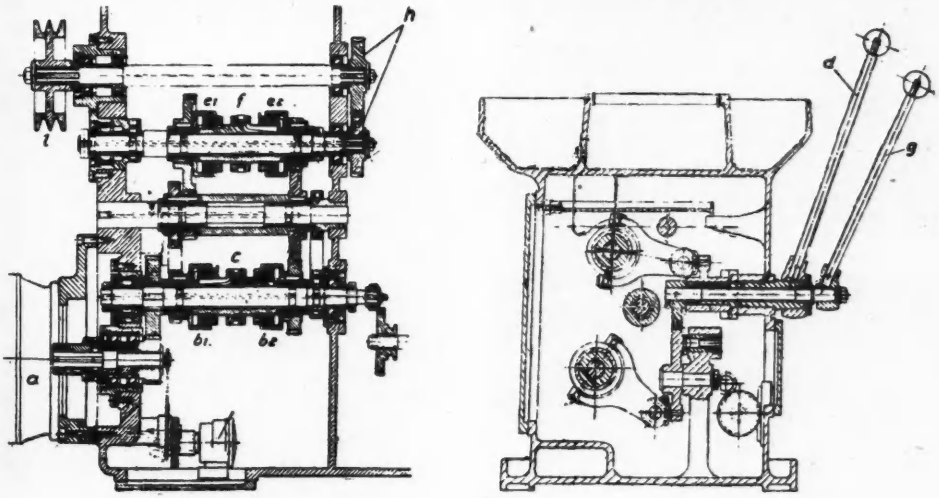


Fig. 3



Figs. 1 and 2.

(a) Drive; (b, b_2, e, and e_2) Disc clutches; (c and t), Movable coupling rings; (d) Lever to operate c (g) Lever to operate t; (h) Spur gears to adjust speed; (l) Pulley.

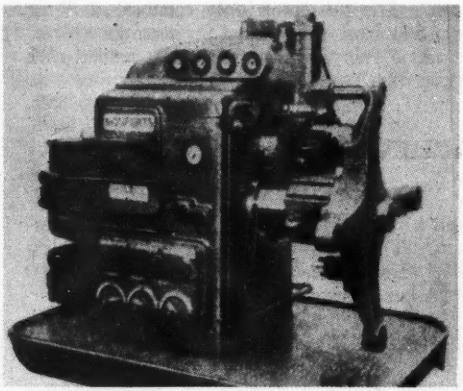


Fig. 4

In Fig. 5 a new type of short thread milling machine is shown. Clamping and charging of the work is hydraulically operated, increasing the output of the machine considerably. Figs. 6 to 10 show the charging process in four phases.

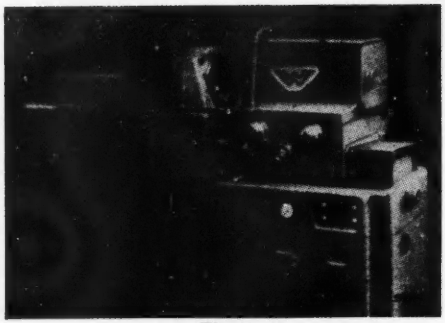


Fig. 5

Fig. 6
Spindle head free.

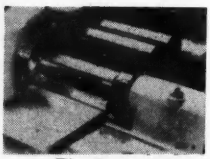


Fig. 7
Work piece hydraulically brought into position.

A machine for milling " Hirth " teeth is shown in Fig. 11. It is used for milling teeth on the end faces of shafts, which are to be coupled together.

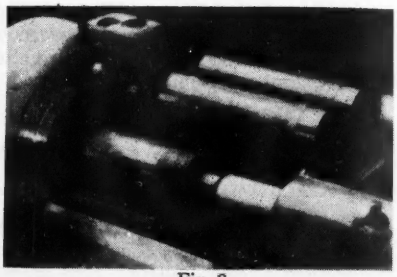


Fig. 8
Work piece during loading of the machine.

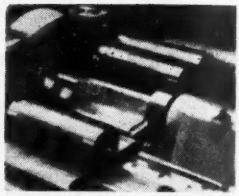


Fig. 9 (left). Work piece in position in the spindle. Fig. 10 (right). Finished work piece rolling out from the machine.

The planogrinder, shown in Fig. 12, has hydraulic drive for the grinding disc, table movement, and spindle. Quiet and chatter-free operation is obtained. After the work has

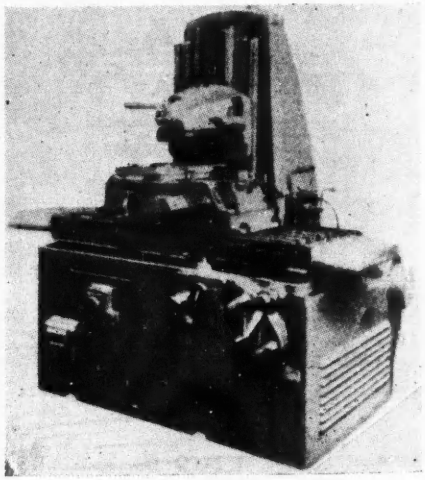


Fig. 11

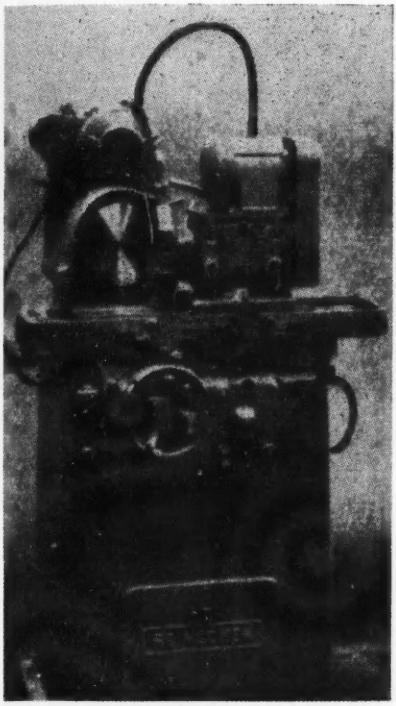


Fig. 12

been brought to the required dimensions, grinding and feed is automatically disconnected.

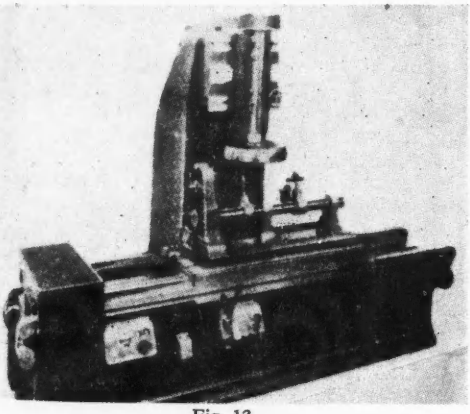


Fig. 13

Fig. 13 shows a fine milling machine. Flat surfaces can be produced with a maximum deviation of 0.005 mm. on work of dimensions 1000 mm. by 200 mm. The irregularity on smaller surfaces is still smaller, about 0.002 mm. Such surfaces can be used as reference surfaces without any further finishing. The machine is also very suitable for milling parallel surfaces,

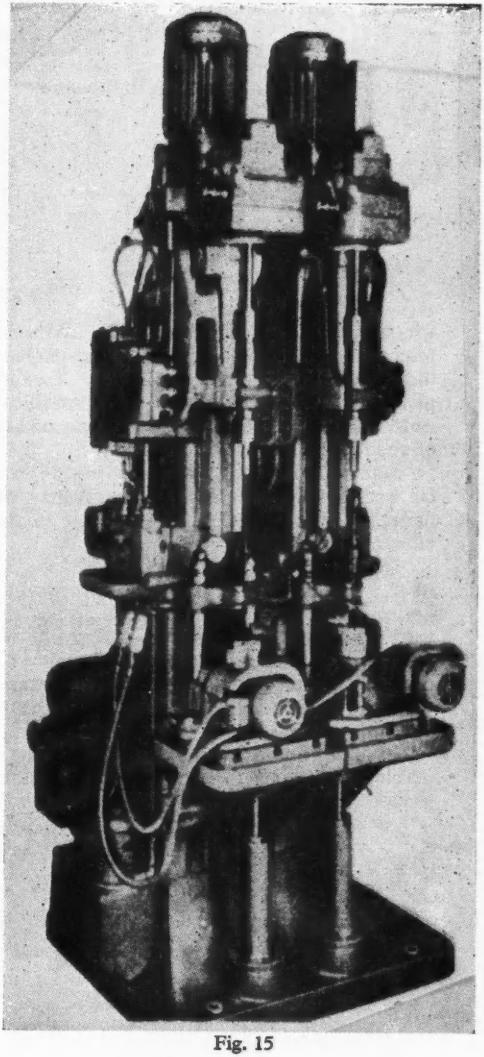


Fig. 15

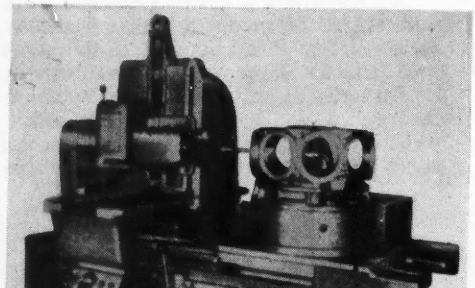


Fig. 14

which are worked simultaneously. Without removing the work, holes parallel and perpendicular to these surfaces can be drilled. Parallel planes on work pieces with a minimum thickness of 3 mm. can be produced with an accuracy of about 0.003 mm. max. deviation.

Standard fine boring machines (Fig. 14) can be used as machine tools if they are fitted with tables, or with spindles perpendicular to the table movement.

Deep-hole boring machines, with one or more spindles, are manufactured in vertical or horizontal type (Figs. 15 and 16). They are used for boring holes, channels and grooves in valves, crank shafts, etc. Continuous discharging of chips, cooling of tool and work, and fully hydraulic operation assure quick and accurate working.

A spline grinding machine (Fig. 17) has been developed recently, on which splines can be ground without preliminary cylindrical grinding.

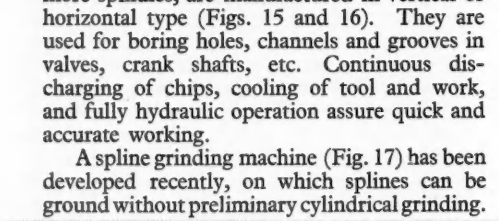


Fig. 16

Fig. 17

Since it is very important to be able to ascertain the accuracy of a toothed gear a side-milling indicator (Fig. 18) has been designed, which determines the dimensions and the accuracy of the teeth in every direction, and gives the result on a diagram.

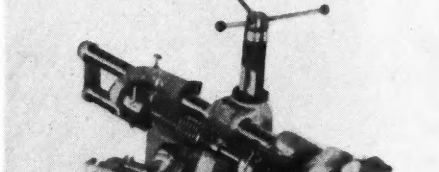


Fig. 18

GAS-BLAST PROTECTOR TUBES

(From *Elektrotechnische Zeitschrift* [ETZ], February 29th, 1940, Vol. 61, No. 9, p. 217).

THE good experience during recent years with gas-blast (chemical resin) breakers equipped with cylinders emitting gas under the influence of an arc, have induced the AEG to employ the same material for protector tubes (expulsion protective gaps). Protector tubes have greatly improved the performance of systems with earthed neutral. In Germany they roused interest as a cheap protective device for small transformer stations, for which ordinary lightning arresters would be too expensive.

The protector tube consists of a tube of special insulating material producing gas under the influence of an arc. In the upper end there is inserted a metal rod as one electrode, while the second electrode consists of a metal ring at the lower open end of the tube. When an excess voltage strikes an arc between the electrodes, the gas liberated in the tube expels the arc downwards and extinguishes it after two or three half cycles.

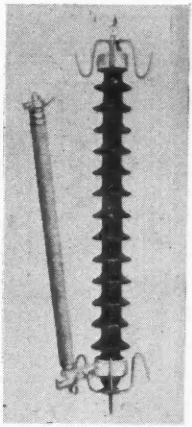


Fig. 1.
Gas-blast protector tube.

The gas-blast protector tubes are manufactured for voltages up to 120kV. Fig. 1 shows such a tube attached to a suspension insulator.

AUTOMATIC VOLTAGE STABILISER

By ING. M. G. LOSINSKY and ING. J. A. KATSMAN. (From *Izvestia Elektropromishlennosti Slabago Toka*, No. 2, 1940, pp. 62-64).

FOR most electric plants constant voltage is essential. In what follows, a single-phase automatic stabiliser will be described, limiting the variations to $\pm$ 1% when the variation in supply voltage is about 15%.

Fig. 1 shows the principal diagram of this stabiliser. The voltage is kept constant by the regulator machine (1), the rotor of which is driven by a squirrel-cage motor fitted with a reducing gear. The motor (2) is provided with a magnetic brake for instantaneous stopping. Relays (3) and (4) are for reversing two phases and are used to start and reverse the motor (2). The terminals of the relays are connected to the anode circuits of two triodes (5) and (6), fed by one of the phases of the network. The cathodes of the triodes are earthed. Resistances (17, 18, 19 and 20) are connected as anode charge to the amplifying valve (10). The grid of this valve is controlled by the voltage difference between the two rectifiers (11) and (13). Rectifier (13) is fed from the network and supplies a positive potential to the grid, while rectifier (11) supplies a negative potential.

With the aid of a small-power ferro-resonance stabiliser the voltage of the calibrating rectifier is kept constant. The rectifiers (14) and (15) supply the anode and grid voltage to the valve (10). The resistances (18) and (20)

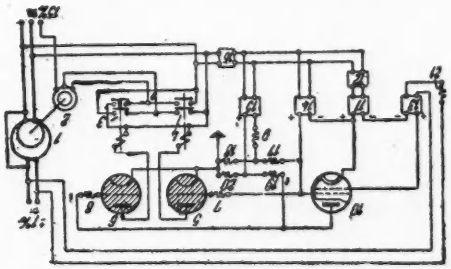


Fig. 1
Principal connection diagram of an automatic single-phase voltage stabiliser.

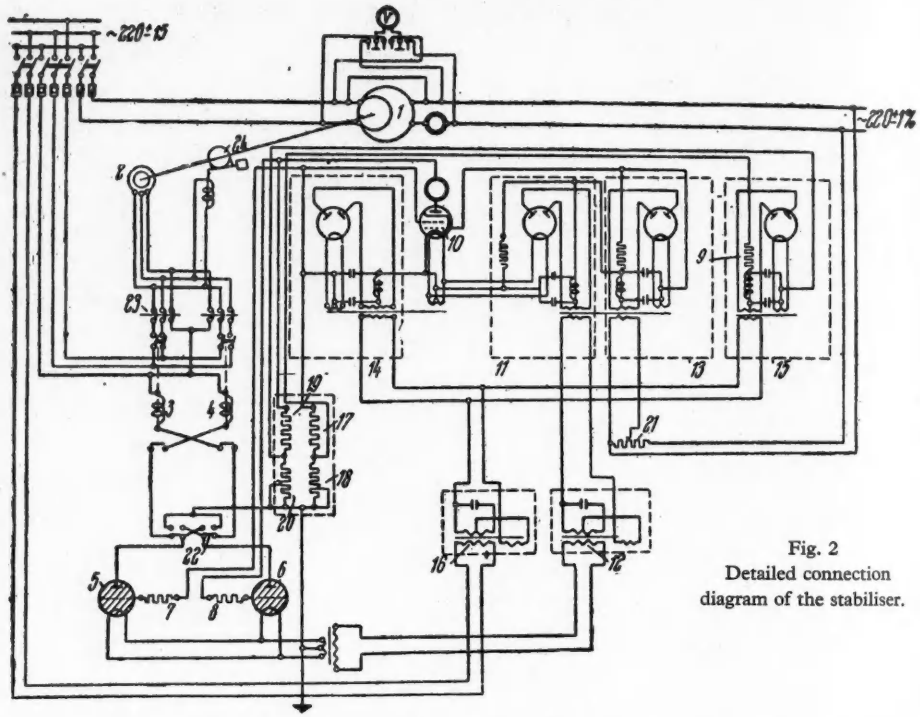


Fig. 2
Detailed connection diagram of the stabiliser.

have one of their terminals earthed and consequently connected with the cathodes of the triodes (5) and (6). The anode current of (10) passes through the resistances (17) and (19) and causes a drop in the voltage, which is supplied to the grids of (5) and (6), the grid of (5) receiving a positive voltage while that of (6) receives a negative voltage. These voltages are compensated by the voltage drop across the resistances (18) and (20), through which the current from the rectifier (15) is flowing.

The resistances (18) and (20), are so selected that the difference in the voltage drop across (17-18) and (19-20) becomes the same as the "locking" voltage of the triodes. Thus, when the system is balanced, no current flows through the triodes.

If the network voltage increases, the grid voltage of the amplifier (10) rises too, causing an increase in its anode current and a greater drop of voltage across the resistances (17-18) and (19-20). Consequently the negative potential of the grid of the triode (6) increases and that of the grid of the triode (5) decreases.

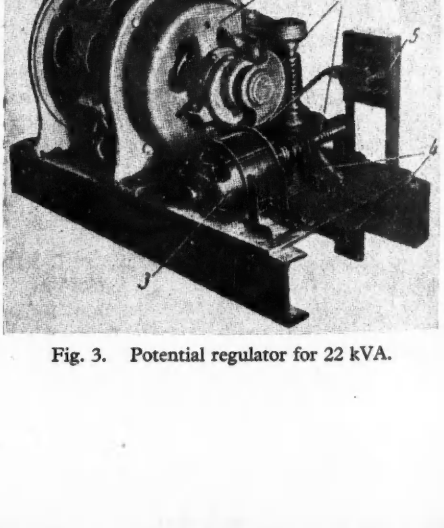


Fig. 3. Potential regulator for 22 kVA.

This causes the triode (5) to operate and switch on the relay (4), which starts the motor (2), and hence the potential regulator (1). Thus the voltage falls until the system is in equilibrium again. If the mains voltage decreases, the triode (6) will operate the relay (3), and the regulator (1) will be rotated in the opposite direction.

The accuracy of stabilisation depends on the amplification of the valve (10), and can be regulated by the resistances (18) and (20). With the aid of the potentiometer (21) in the primary winding of the anode transformer, the voltage across the rectifier can be changed. If this voltage is increased the stabilisation is effected at a lower voltage, and vice versa.

The complete connection diagram is shown in Fig. 2. A pentode is used as amplifier and diodes as rectifiers. The filters of the rectifiers are made up of electrolytic condensers each of 10 μ F., 450 V. and choke coils of the type DV-16. (17, 18, 19 and 20) have 2500 ohms resistances; (22) is a switch to start the motor; (23) is a speed limiting device; and (24) is a magnetic brake.

Fig. 3 shows the potential regulator (1), the reduction gear (2), the reversing motor (3), the brake (4), and the speed limiting device (5).

The stabiliser can be equally well used for single-phase and multi-phase system. In the latter case a single-phase stabiliser is used in each phase.

AUTOMATIC FEED REGULATOR WITH OIL CONTROL FOR BOILERS

(From *Schweizerische Bauzeitung*, Vol. 116, No. 26, 28th December, 1940, pp. 303-304).

MOST of the boiler feed regulators have the disadvantage that the operation is greatly influenced by impurities in the feed water. A more reliable feed regulator, which is particularly suitable for larger installations, has been designed, therefore, by the firm, Gebrüder Sulzer. It consists principally of a feed water container with a levelling bottle, a slide valve and an oil controlled feed water valve.

Fig. 1 shows the arrangement of the regulator, while Figs. 2 and 3 show the levelling bottle and the feed regulator valve. The operation of the regulator is as follows: the levelling bottle fitted next to the boiler, can move in a vertical plane and is connected by means of flexible tubes to the water tank and steam chest of the boiler. Thus the water in the levelling bottle is adjusting itself to the same level as that in the boiler. Vertical movements of the levelling bottle are transmitted to the piston of an oil pressure regulator, which controls the feed regulator valve. So the feed water is throttled to a greater or lesser extent until the required water level is reached in the levelling bottle and hence also in the boiler. The vertical movements of the levelling bottle are gravity controlled, that is, if the water level is rising the excess weight of the water in the bottle lowers the levelling bottle, and falling of the water level causes the bottle to rise again. Hence the water level in the boiler is kept within narrow limits, and no hand controlling is needed.

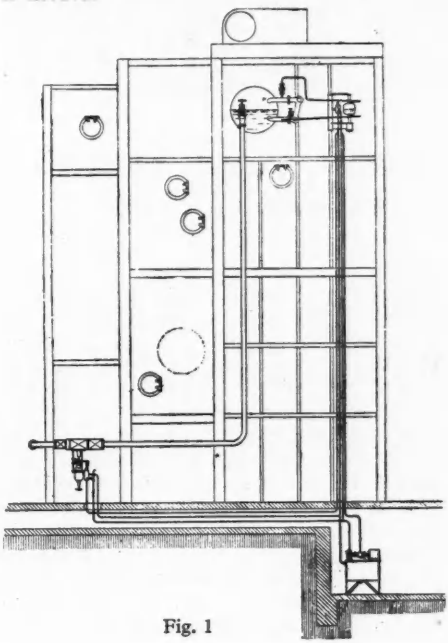


Fig. 1

A toothed gear pump is supplying the oil pressure (about 6 atm.) to the control system. Impulses are given to the oil pressure at regular intervals to keep the parts of the regulator in constant motion to avoid jamming and to kill friction.

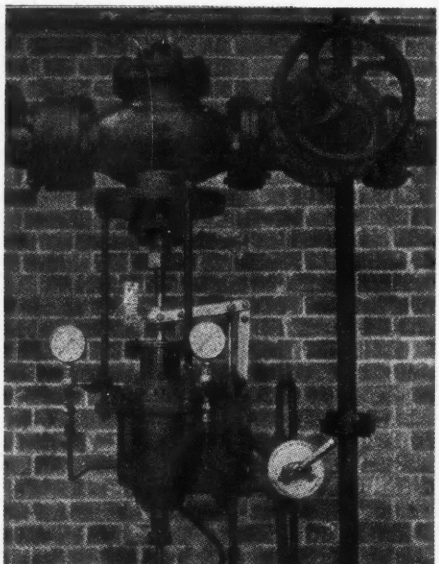


Fig. 2.

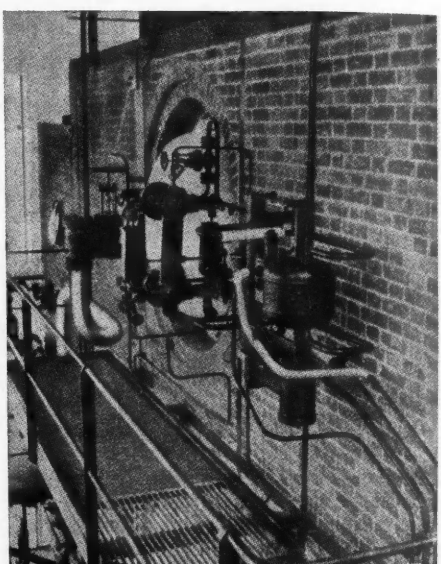


Fig. 3.

HEATING IN WINTER TIME WITH SURPLUS SUMMER ENERGY

By PAUL SEEHAUS. (From *Bulletin of the Schweizerischer Elektrotechnischer Verein*, July, 1940, Vol. 31, No. 15, pp. 317-31).

FOR countries like Switzerland, which possess abundant sources of hydraulic energy but no coal mines, electric heating is one of the most interesting and urgent economic problems. The Annual consumption of a residence may amount to 4,500 lbs. of coke, equivalent to 8×10^6 kCal, when the losses of the furnace installation and the irregularities of heating are taken into consideration. The annual Swiss import of fuel amounts to 16.600×10^9 kCal. 17×10^9 kWh would be necessary to substitute this quantity of fuel by electric energy. It would be possible to develop waterpowers in Switzerland, the annual output of which would be equivalent to the imported fuel, but the production of electric energy of these power plants would not coincide temporarily with the need of the heat. The maximum demand of a complete electric heating of Switzerland has been estimated as high as 13×10^6 kW, whereas the maximum load of the power plants, which could be developed economically, would not exceed 2.5×10^6 kW in winter time. Therefore, the problem of storage of energy during summer when the Alpine water power has maximum production, is of greatest interest.

Up till now one has practised storage of the surplus of energy during summer in hydraulic accumulators, but the study of Mr. Seehaus shows that caloric accumulation has some chance to be used too. It is of interest to state, that for the production of 1 kWh, 1 m^3

of water has to be stored in a basin with a fall of 367 m, whereas 81 kWh can be accumulated. in 1 m³ water by heating from 25° C. to 95° C.

Storage of energy by heating of water becomes the more economic the greater the accumulator used, as the surface, and therefore, the energy losses are proportional to the square, the quantity of stored energy to the cube of the linear dimensions of the accumulator. Table I gives the loss of heat of spherical accumulators, properly insulated with ground cork, when filled with water at 100° C. This table shows that such accumulators would give a very good efficiency even for cycles of several thousand hours, as they would occur when summer energy is stored for heating during winter time.

TABLE I.

Content of heat of spherical water accumulators after a cooling time of t hours.

(Figures are % of original content of heat).

Temperature of hot water, 100° C.

Time of cooling t hours.	Volume of accumulator m³. 0.8	1	10	100	1,000	10,000
	1. Accumulator with insulation.*					
10	93	95	99	100	100	100
100	48	62.5	89.5	97	100	100
500	2.7	10.4	56.7	87.5	97	99.5
1,000	—	0.9	32.5	77.5	94.5	98.7
2,000	—	—	10.5	60.5	89.5	97.5
4,000	—	—	1.1	37.0	80.5	94.0
8,000	—	—	—	13.0	65.0	90.5
	2. Accumulator without insulation.					
10	70	76	88	93	97	99
100	2.6	5	26	53.5	76	88
500	—	—	—	4.4	23.6	51
1,000	—	—	—	—	5.5	26
2,000	—	—	—	—	—	7

*The insulation consists of ground cork, volumen 24.55% of the volumen of the water.

Two types of accumulators are of practical interest: Storage of the heat in water, and storage in the soil. Results of calculations based on practical assumptions are very encouraging.

Hot water accumulation.

An accumulator, as shown in Fig. 1, with a content of 3,000 m³ would suffice to heat 26 residences during the whole winter, if the water heated to 95° C. during the summer would be cooled to 25° C. during winter, under circumstances as prevailing in Switzerland (average temperature of the air 7-8° C.). The tank may

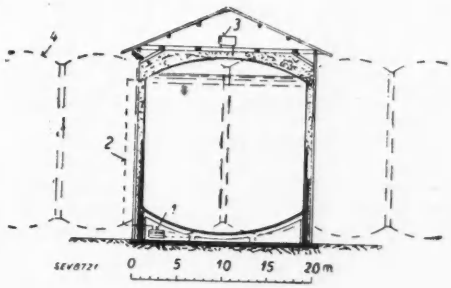


Fig. 1

Hot water accumulator with a useful content of 3,000 m³.

(1) Electric heating device. (2) Circulating device. (3) Device for the elimination of air. (4) Later extensions.

be made of boiler plate or ferro-concrete. A ground cork insulation of 40 cm. thickness prevents undue losses of heat. Table II gives the calculated result for such an accumulator.

The difference of the cost of 1,000 kCal generated by a central heating plant supplied with fuel at the rate of 75 Swiss frcs./t and a hot water storage plant as described above, heated by electric energy at the rate of 0.007 frcs./kWh, both sufficient for 26 residences, amounts only to approximately 10% in favour of the caloric plant.

TABLE II.

Accumulator of 3,000 m³.

(Approximate surface of the tank: 1,100 m²).

Maximum of difference of temperature	70° C.
Heat corresponding to this difference of temperature	210×10^6 kCal
Sufficient to heat 26 residences	243.000 kWh
Average load during the period of storage	65 kW
Average annual temperature of the water	60° C.
Average temperature of the ambient air	7° C.
Loss of heat of the accumulator during one year	41.700 kWh
Efficiency	85.4%

Accumulation in solid materials.

For the accumulation of very great quantities of energy, the author proposes to use solid materials instead of water as, for instance, the solid mass of ground, limestone, sandstone or granite which are most suitable, due to their high specific heat. As a spherical shape of the accumulator gives the best efficiency, it is pro-

posed to heat a hemispherical part of the soil as shown in Fig. 2.

Heat is transmitted to the soil by heating the water contained in wells (2) of appropriate depth distributed throughout the hemispherical

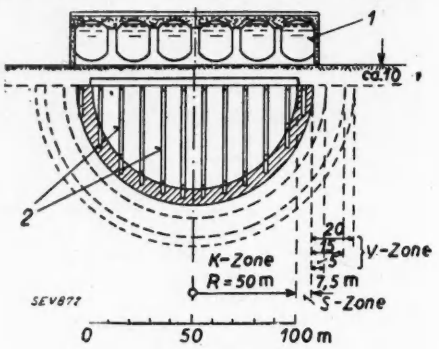


Fig. 2.

Fundamental sketch for an accumulator using the mass of the soil.

(The original publication contains a figure showing the temperature of the zones, indicated in th s figure, during the first two years and the final distribution of the temperature).

form of the accumulator. They are equipped with devices for heating and circulating the water. Loss of heat to the atmosphere is minimised by a layer of earth of 10 m. thickness (3), and, if there is a need of warm water, by reservoirs (1) placed on top of it. It is assumed that the mass of the soil or rock within the hemisphere will be heated during summer up to 95° C., and cooled during winter down to 25° C., thus producing a caloric oscillation. The zone surrounding the heated hemisphere participates, of course, in the caloric oscillation of the accumulator. But only the temperature of the innermost zone (for instance, a zone of 7.5 m. in a case of an accumulator of 100 m. diameter, as shown in Fig. 2) will vary in nearly the same range as the part of the soil forming the accumulator. The amplitude of the temperature of the zones decreases with the distance of the zone from the accumulator. The duration of one cycle is one year. The average temperature of the soil is highest in the zone near the accumulator and it can be assumed that with an accumulator of 100 m. diameter, a zone of approximately 7.5 m. will have nearly the same average temperature as the accumulator itself and will participate in some way in the storage. The average temperature of the zones farther distant will decrease with the distance: e.g. in the second year the average temperature of the soil in a distance of 22.5 m. from the circumference of the accumulator would have risen from the previous temperature of the soil, assumed as 7° C., to an average temperature of about 25° C. It will take, of course, many oscillations, i.e. many years till the final distribution of temperature is approached. The paper gives a detailed mathematical investigation of the problem from the caloric point of view, and a numerical calculation with the result summed up in Table III.

TABLE III.

Economy of an accumulator in limestone.

Diameter of the accumulator, 100 m.; sufficient to heat about 1,400 residences.

	Period of starting of the accumulator	1 Year	2 Years
Supply of heat kCal..	6.521×10^9	12.694×10^9	12.222×10^9
Useful heat	—	11.251×10^9	11.251×10^9
Supply of electric energy kWh ..	7.55×10^6	14.69×10^6	14.14×10^6
Utilised form of heat	—	13.02×10^6	13.02×10^6
Average load during storage kW ..	3,450	3,350	3,220
Efficiency % ..	—	88.7	92.2

GLASS IN SUCCESSFUL COMPETITION WITH OTHER MATERIALS

By ING. O. PRIDAL. (From *Sklárské Rozhledy*, Vol. 17, 1940, No. 3, pp. 55-59).

MANY attempts were made to replace plate-glass with organic substances, so-called organic glasses. But even the best products of the organic industry lacked a sufficient surface hardness, although they had many of the good qualities of glass. There are a few applications of organic materials, e.g., for airplane windows, since they have good elastic properties, are flexible and have comparatively light weight. Due to their small surface hardness, they get scratched very quickly and their transparency decreases. It cannot be expected

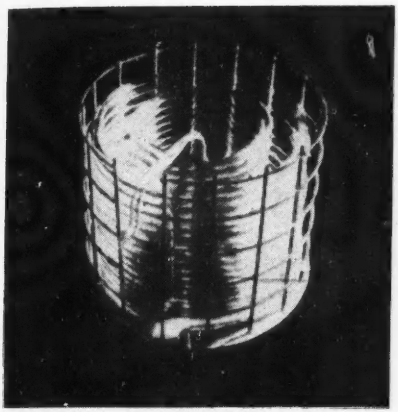


Fig. 1.
Glass heating worm for industrial water-heating.

that organic glass will be produced in the near future with a surface hardness equal to that of inorganic glass, more likely is the production of a more elastic and perhaps lighter glass, probably by chemical influence on the texture of the glass.

Domestic glassware, glass packings, and decorative glass have been temporarily replaced by various materials, but glass has always been victorious in the competition. The prominent qualities of glass guarantee that as a raw material it will penetrate more and more into new branches. Glass might be expected to replace other raw materials, mainly metals and wood.

Fig. 2. Glass centrifugal pump for acids. Output over 27,000 litres per hour.

In chemical, pharmaceutic and medical research laboratories glass is almost unreplaceable due to its high resistance against chemical and thermal attacks, and its high melting point. Glass electrodes for scientific measurements have been produced lately, with a specific resistivity of only 0.3 to 0.6 megohms. The excellent mechanical and chemical resistivity of these glasses renders them suitable for routine testing in plants.

For X-ray tubes glass is indispensable, as it must let pass the X-rays, endure the electric strain, and be perfectly gastight to keep the vacuum in the tubes unchanged. Protective anti-X-ray screens are a typical example how glass, by changing its chemical composition, may entirely replace metal. Glass plates containing about 70% PbO, not only replaces lead plates, but have the advantage in addition to be perfectly transparant.

In medicine, glass is used for vials, syringes, sterilization vessels, artificial teeth and recently also for corrective lenses put directly on the eye. In the chemical and food industries the thermal and chemical resistivity of glass is made use of, and various instruments are manufactured on a big scale.

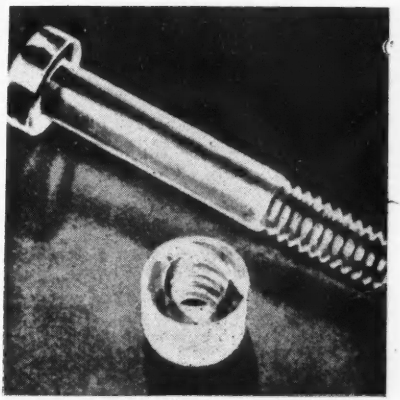


Fig. 3.
Glass Screw and Nut replacing metal in contact with corrosive acids.

Glass can be easily machined, cut, ground, polished, bored, turned and provided with threads. For these purposes sintered carbides are useful. Fig. 3 shows a glass screw with nut. Fig. 4 is the model of a glass calendar, the rollers of which are turned together with the bearings, out of one piece of glass. The frame-plates have drilled holes for the screws which fix them to the base-plate.

Long pipe lines are built from glass tubes for the transport of corrosive liquids, hot concentrated acids of foodstuffs. Pipe lines

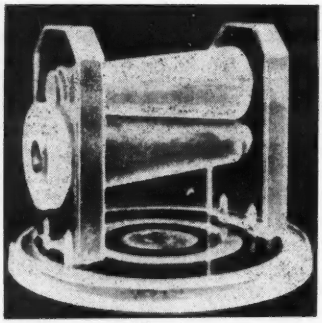


Fig. 4
Model of a glass calender.

reaching a length of 80 m. and a diam. of 40 mm. are successfully used in breweries. Tubes with smaller diameters stand up to 50 atm. pressure, those with larger diameter with joints endure 5 to 10 atm.

Glass is indispensable in the vacuum technics for its transparence, gas-tightness and suitability for machining. No special requirements are demanded as for quality, the common type suffices.

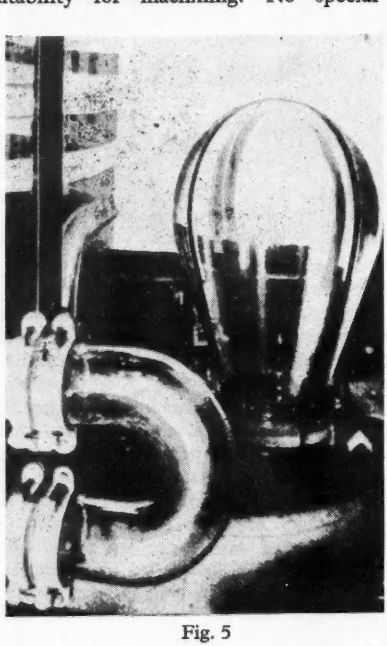


Fig. 5
Glass tubes and inner vessel of a boiler for hot water. Capacity 100 litres.

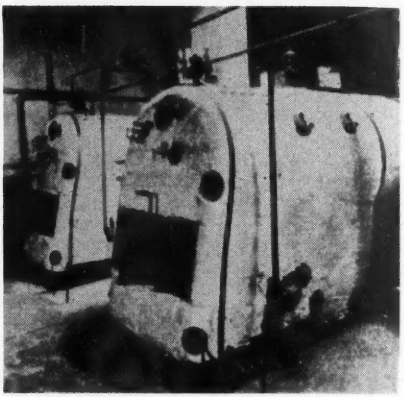


Fig. 6
Dismantable insulating of steam boilers, made from glass felt.

Glass boilers for hot water, heated by electric current, have been well received (Fig. 5). Usually they are of 50, 80 or 100 litres capacity and are made of tinned sheet-copper. According to German standards, they should be able to withstand 3 atm. and a change of tem-

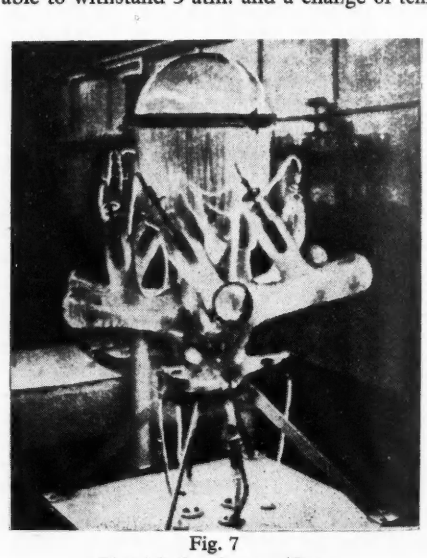


Fig. 7
Big vial of a glass rectifier.

Fig. 8. Chain of insulators for 110 kV, with an arc of 350 kV.

perature up to 150 C. In a German power station about 200 boilers of capacities 10 to 100 litres, have been used for several years. Very few leakages have occurred, with a deposit of about 1/5th of that of copper boilers, but formation of a granular mud was found.

The textile industry is making use of glass fibres. They are of very small dia. (sometimes about 1/1000 mm.). The fibres are spun and woven to different fabrics for decorative or industrial purposes. Protective clothes are made of glass yarn. The insulating property of glass-wool is three times that of asbestos, while its specific weight is only 1/6th of asbestos.

In the U.S.A. glass wool was tested for winter protection of plants. The results were very favourable, although glass-wool was used in layers two to three times thinner than those of other materials.

In the electro-technik glass was always widely used, but in recent times it is used in a still wider extent, owing to the improvements of its qualities. It is used for mercury-arc rectifiers high tension insulators. Glass yarn is used for insulating wires, especially for coils of dynamos and motors. For accumulators, glass-wool is used too, a thin layer covering the plates and improving the capacity of the accumulator by as much as 40%.

Another example for the successful replacement of metal by glass are the kerb-stones with a reflecting effect, made of moulded or ground glass and reflecting the light of the headlamps in different colours. They replace signal lamps on roads, tracks, and at railway stations. Constructional engineering and architecture is also employing glass in various forms and shapes. It is conspicuous for its cleanness, resistance to heat, pressure, impacts, and insulates against sound and heat. Walls are built from hollow vacuum bricks and in some cases from foam bricks. For panelling, glass is suitable due to its sparkling qualities.

Hardened glass-plates are used for vehicles, having up to six times the bending and impact strength of ordinary glass. In the inner architecture too, glass replaces metal and wood, not only for doors and panelling, but also for furniture, sliding walls, stairs, etc.

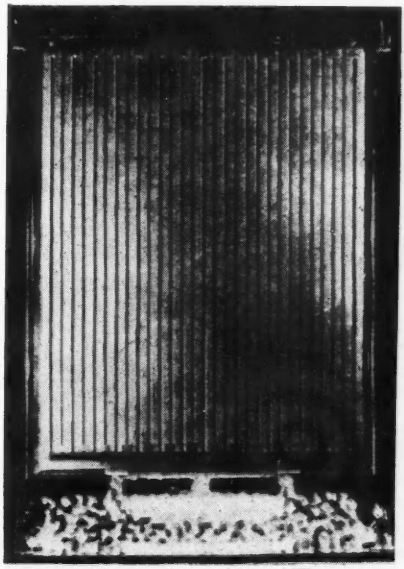


Fig. 9 Glass radiator of 1000 kW output.

MEASUREMENTS ON DETONATION IN DUCHENE APPARATUS

By G. BROERSMA. (From *Journal of the Aeronautical Sciences*, Vol. 8, No. 2, December, 1940, pp. 62-71).

[*Measurements on the Duchene apparatus were made at the "Proefstation Delft" to investigate whether the mechanism of detonation with this apparatus differed from that found with the "Delft" window engine*].

CONTEMPORARY theoretical approaches to the problem of detonation in engines may be classified as follows:

(1) Detonation in engines may be identical with that found in tubes under certain condi-

tions. The speed of the flame front suddenly increases to speeds greater than that of sound.

(2) Detonation in engines may be a phenomenon occurring primarily in the end-gas by self-ignition of a finite position of the latter, causing an explosion, i.e., for a combustion where heat is produced at such a rate that transport of energy by conviction and radiation is replaced primarily by transportation of energy by diffusion, resulting in a detonating combustion wave.

(3) Detonation in engines is a phenomenon occurring primarily in the end-gas by self-ignition of infinitesimally small volumes at one or more points ahead of the flame front, creating one or more flame fronts proceeding at normal, subsonic speeds.

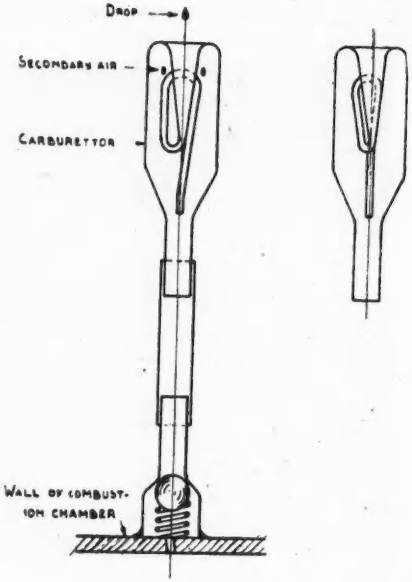
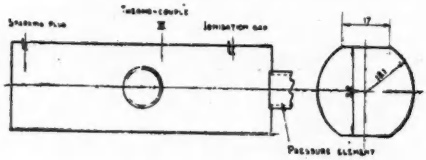


FIG 1



LOCATIONS OF
SPARKING PLUG THERMO-COUPLE PRESSURE-ELEMENT AND IONISATION GAP
IN COMBUSTION CHAMBER IN DUCHÊNE-APPARATUS

FIG 2[a]

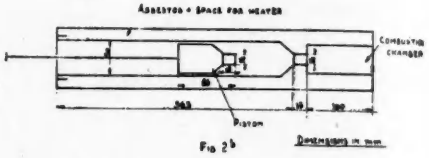


FIG 2[b]

The following changes were made in the original apparatus (Fig. 2 shows the cross section of the apparatus proper):

(a) Fuel was dripped into the glass carburettor as shown in Fig. 1.

(b) One of the windows was first replaced by a steel plate containing four thermocouples, and later, spark plugs for ignition and ionization gap were inserted.

(c) A hole was drilled midway in one side of the combustion chamber and a pressure element was inserted; during the photographic recording a spark plug was screwed into this hole (Fig. 2a).

The piston was pushed into the cylinder by hand until it seated. Then 4 to 6 drops of fuel were administered into the carburettor from a dripping apparatus. After that the piston was pulled out to the position comparable with the position of bottom dead centre of an engine. Lastly, a pressure of 11 to 12 atm. was suddenly released behind the piston. At the end of the stroke ignition occurred.

The apparatus is to be compared with an engine having a speed of 300 r.p.m., a compression ratio of 7, and a combustion chamber of 96 cc. volume.

The mixture strength ranged from about 0.95 to about 1.55. The temperature, at the point inside of the combustion wall, 58 mm. from the piston side, was 60 to 140° C.

Fuels	Octane rating
Isooctane/n-heptane blends	0, 10, 20, 30, 40, 50, 60, 70
A reference fuel	42 1/2
Same reference fuel with benzene	50
Dutch commercial fuel	70

During the simultaneous ionization and pressure measurements the test conditions were:

Mixture strength	0.38
Temperature at point III, with the arrangement of the combustion chamber as shown in Fig. 2a, except that the ionization gap replaced the spark plug shown, and the pressure element was halfway along the combustion chamber, and the spark plug replaced the pressure element ..	75.6°-96.1° C

Temperature at point III, with the arrangement of the combustion chamber as shown in Fig. 2a: 81.0°-89.2° C and 80.9°-93.1° C

Flame Pictures. The photographic apparatus contained a rotating drum such that 1 mm. on the film corresponds to 2.47×10^{-4} sec. Each series of measurements consisted of five flame pictures taken consecutively on the same piece of paper. During each of the five measurements the number of drops administered from the dripping apparatus was the same.

A series of measurements was carried out for three mixture strengths, from about 0.95 to about 1.55, of each of the fuels mentioned above. The following results were obtained:

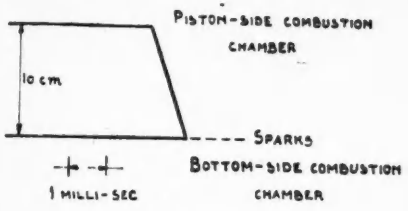


Fig. 3a.

Fig. 3b.

Fig. 3c.

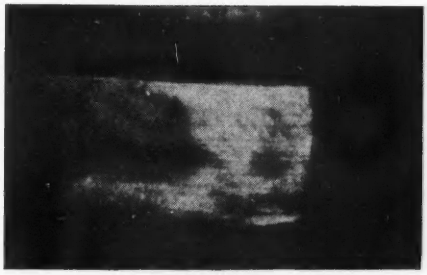


Fig. 3d.

Fig. 3e.

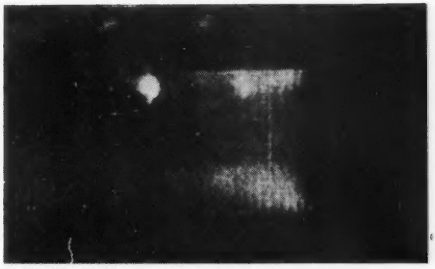


Fig. 3f.

(a) Normal combustion.
Fuel: blend of 70% isooctane and 30% n-heptane, by volume.
Octane Number, O.N. = 70, Mixture strength, m = 1.16.
Temperature at point III, T_{III} = 130.5° C. (See Fig. 3a).

(b) Normal combustion with "Combustion en bloc" at the end.
Fuel: Reference fuel, O.N. = 42 1/2, m = 1.29, T_{III} = 99.4° C (Fig. 3b).
Fuel: 89% reference fuel and 11% benzene, O.N. = 50, m = 1.28, T_{III} = 101.3° C. (Fig. 3c).

(c) Normal combustion turning into combustion at sonic or supersonic speed.

Fuel: Petrol, O.N.=70,m=1.24, T_{III} = 66.5° C. (Fig. 3d).
Fuel: n-heptane, O.N.=O,m=0.95,=T_{III}= 91.6° C (Fig. 3e).

(d) Sonic wave starting from the piston.
Fuel: blend of 10% isooctane and 90% n-heptane, O.N.=10,m=1.15, T_{III}=108.5° C (Fig. 3f).
Fuel: n-heptane, O.N.=O,m=1.14, T_{III}= 86.9° C (Fig. 3g).

(e) Normal combustion and self-ignition of the end-gas.
Fuel: blend of 70% isooctane and 30% n-heptane, O.N.=70,m=0.95, T_{III}=139.1° C (Fig. 3h).

(f) Self-ignition before the spark occurs.
Fuel: blend of 70% isooctane and 30% n-heptane, O.N.=70,m=1.16, T_{III}=136.0° C (Fig. 3k). The bright spots in Figs. 3f to 3k are reflected images of the small mirror used for the visual observation of the flame.

The speeds of sound in the unburnt gas were calculated for the cases of combustion mentioned under "Normal combustion turning into combustion at sonic or supersonic speed." The orders of magnitude of those speeds and the combustion speeds occurring in critical stages are shown to be the same, viz., about 500-1100 meters/sec.

Fig. 3g.

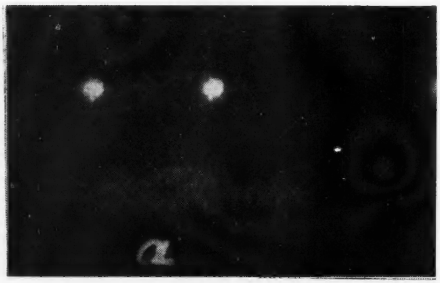


Fig. 3k.

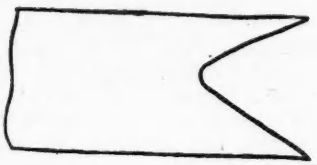


Fig. 3h.

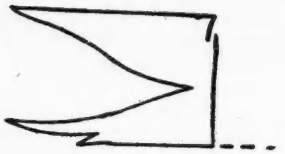


Fig. 3i.

Fig. 3j.

The gas vibrations are very easily started after an impact between two flame fronts, or a flame front with a wall. The frequency of the vibrations is from 5400 to 5800 Hz.

The following kinds of combustion may be indicated: normal combustion, detonative combustion, normal combustion + self-ignition, pre-ignition. Detonative combustion occurs in a small region only.

There is sometimes a feature to be observed in flame pictures of real detonative combustion; a picture of normal combustion appears to be superimposed on a picture of combustion in a detonative wave. The combustion is far from being complete in the detonative wave. Pressure records to be treated later revealed the same phenomenon.

Weinhart carried out qualitative research of detonation in vessels and real engines by studying the character of the ionization diagram. The typical differences in ionization diagrams found for the two cases of detonative combustion correlated with differences in the pressure records taken simultaneously. On the Duchêne unit the same experiments were made, using a 10 mm. spark plug as ionization gap (gap width 0.5 mm.) and the Delft quartz pressure element for the pressure recording. 150 Volts were impressed on a circuit with the

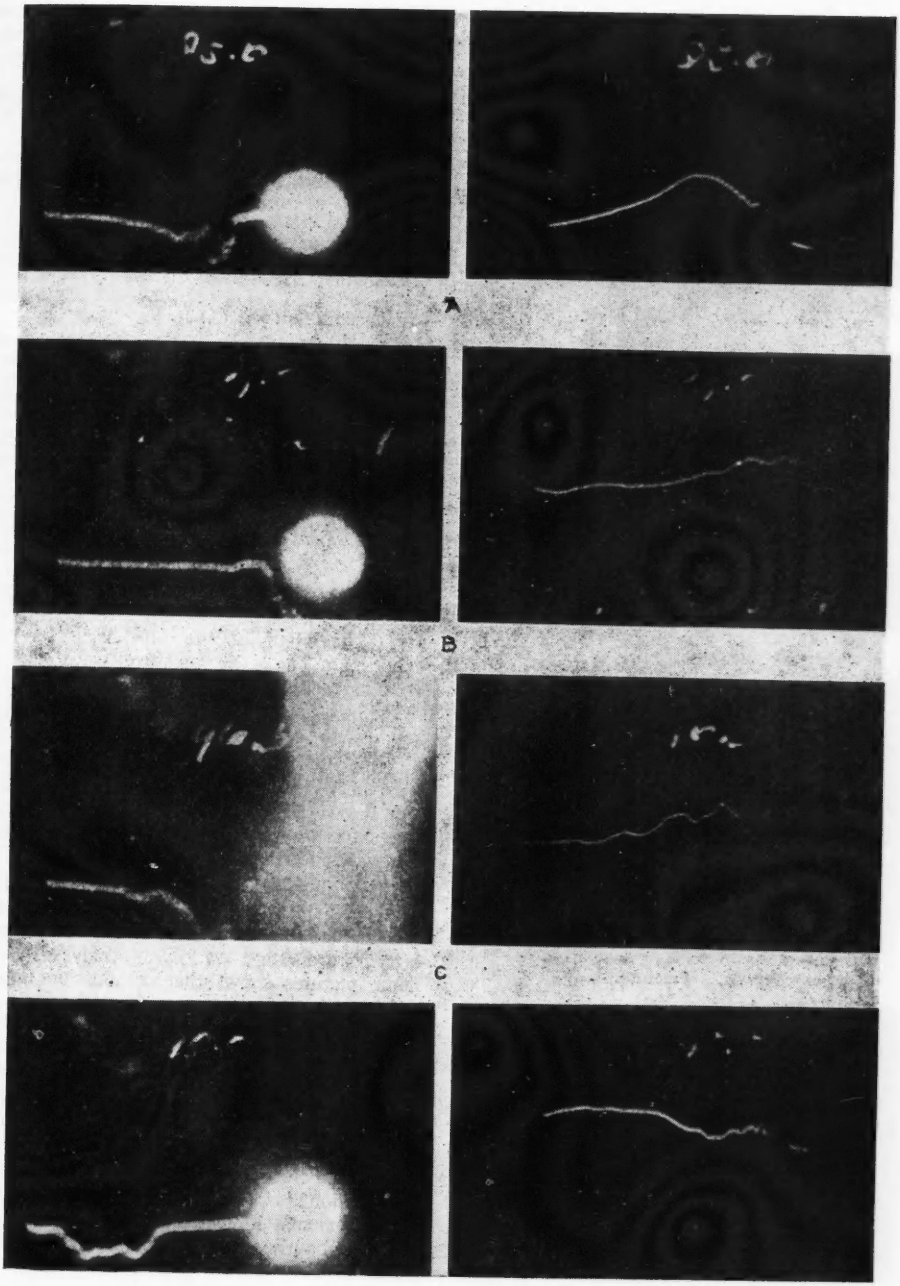
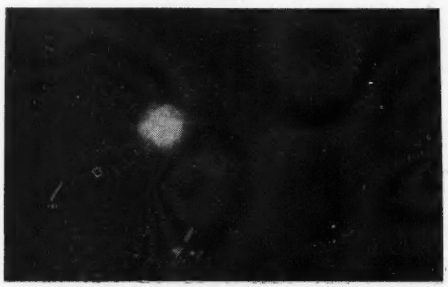


Fig. 4.

gap with 1 M Ω and a cathode ray tube in series. Pressure recording was done by a unit constructed by one of the laboratories of the Dutch Post Telegraph and Telephone Co. (P.T.T. unit). The sweep of the electric cathode-ray tube was coupled to that of the P.T.T. unit (the diagram length was 0.0204 sec.). The aim was to localize the phenomenon of real detonation. Therefore, the combustion of fuel and mixture strength, which had shown a typical flame picture, was taken, viz., fuel: blend of 10% isooctane and 90% heptane, T_{III} = 75.6° C to 96.1° C. and 80.9° C. to 93.1° C. (Figs. 4 and 5), m=1.38. A range of the temperature T_{III} was examined for typical pressure and ionization diagrams. The phenomena was found in a small temperature range, about 3° C. in width. The range varied in the neighbourhood of 80° to 85° C., depending on uncontrolled circumstances, e.g., humidity of air, outside temperature and pressure, etc. Figs. 4 and 5 show photographs taken on two different days.



Ionization.

Fig. 5a. Pressure.

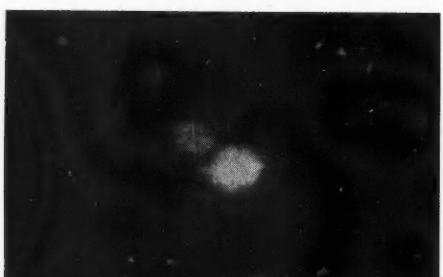


Fig. 5b.

Summarizing, the following typical combinations of pressure and ionization records were found (time increases from right to left):

(1) Normal pressure diagram together with a normal ionization diagram. Temperature $T_{III}=t_1°$ C (Fig. 5a), $T_{III}=81.7°$ C.

(2) Continuous pressure diagram with vibrations, together with discontinuous ionization diagram with vibrations, $T_{III}=t_2° C>t_1°$ (Fig. 4a) $T_{III}=85.6°$ C.

(3) Discontinuous pressure diagram with or without small vibrations, together with discontinuous ionization diagram with or without vibrations. $T_{III}=tk>t_2°$ C (Fig. 4b), $T_{III}=89.0°$ C. and (Fig. 5b), $T_{III}=82.7°$ C.

(4) Continuous pressure diagram with vibrations in the ascending portion, with or without vibrations in descending portion, together with discontinuous ionization diagram with or without small vibrations afterwards, $T_{III}=t°_4$ C>t°k C. (Fig. 4c), $T_{III}=96.3°$ C, & (Fig. 5c), $T_{III}=90.6°$ C.

(5) Continuous pressure diagram, with or without small vibrations in the descending portion, together with continuous ionization diagram without vibrations, $T_{III}=t°_5$ C>t°4 C (Fig. 4d), $T_{III}=90.0°$ C, and (Fig. 5d), $T_{III}=87.7°$ C, & (Fig. 5e), $T_{III}=93.1°$ C.

Fig. 4 shows that the distance between two subsequent pressure peaks is about $1/4 \times 10^{-2}$ sec. The length of the pipe used for the experiment, i.e., the pressure wave moved at an average speed of 500 m/sec.

The order of magnitude of the pressures which were visibly recorded in the present diagrams is about 40 to 50 atm. Higher values escaped recording as indicated by the discontinuous character of the pressure diagrams. Fig. 5d is typical; here the pressure diagram was swept off the cathode-ray tube.

It is shown that physical detonation may occur in the Duchêne apparatus. Actually the phenomena has been localized in a narrow temperature range, *cet. par.* Analysis of the flame pictures shows that combustion is occurring at speeds comparable with those of sound in the end-gas, under the existing thermodynamic conditions. Theoretically, physical detonation occurs for one temperature range, all other conditions remaining the same.

It also appears that combustion takes place in which the detonative combustion is not complete. Superimposed on the detonative combustion is a slow normal combustion. This particular kind of combustion occurs in the neighbourhood of the real detonative combustion.

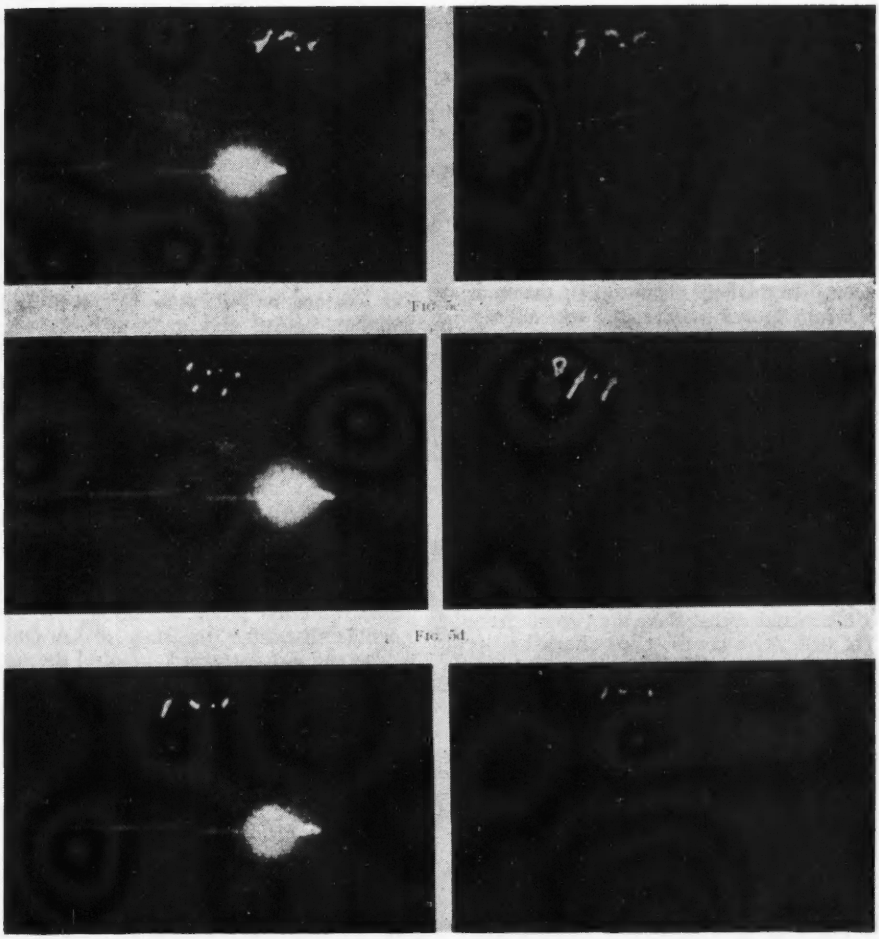


Fig. 5e.

Relative to the correlation between photographic results and the ionization and pressure recording it appears that Figs. 3a ; b, c ; 3d, e, f, g ; 3h ; 3k correspond, respectively, with Figs. 5a ; 4a ; 4b, 5b ; 4c, 5c ; 4d, 5d, e.

Accepting the results of different experiments on combustion and knowing the conditions of these experiments, one must try to build up a general view covering the experiments.

Starting with the phenomenon of detonation in tubes it has been remarked that the normal combustion always breaks into detonative combustion at the same spot, all other conditions remaining the same. Gauze screens may change the position of this particular point, when they are placed before the point where the normal combustion has broken into detonative combustion. When placed behind this point, the screen is destroyed without in-

fluencing the position of the critical point, except when this occurs near the end of the tube. This agrees with Véron's theories, based on experimental evidence, in which the apex of the curved flame front, at a certain point, is pushed back. The small column first contains burnt gases, then becomes partly filled by fresh gases, while retaining some of the burnt gases. As a result of diffusion and flame movement near this apex, mixing of fresh and burnt gases occurs. The fresh gases, heated to a high temperature, will burn so rapidly that energy is practically transported by diffusion. In the light of the kinetic theory of gases, common combustion may be viewed as a transport of energy of the molecules by convection and radiation. As a result of the explosion, a mass of molecules of higher impact values than before is given off into the molecules of the fresh gases, and these are also ignited at a value of combustion speed comparable with the speed of the molecules. In engines the phenomenon of detonation is supposed to be either the same as that in tubes or due to self-ignition of the end-gas, which again may either cause combustion proceeding at a normal speed or at a supersonic speed.

It is concluded that there are two mechanisms of detonative combustion. Each has its own critical stage and its own time constants. One is physical, the other is chemical.

The physical phenomenon of detonative combustion is the detonation occurring generally in tubes, bombs, and other vessels. By physical process of aerodynamical flow, mixing and diffusion, a critical stage is reached from which the flame front proceeds at supersonic speed. The occurrence of the critical stage at a certain point depends upon the width of the tube, the pressure, and upon whether the tube is opened or closed.

Temperature has little influence and anti-knock agents have little or no effect. Increasing initial pressure brings about earlier detonation, up to a certain limit.

The other phenomenon of detonative combustion is that which occurs generally in engines. By chemical reactions, a critical stage is reached in which the end-gas ignites at one or more points. Combustion proceeds from these points at normal, subsonic speeds. In the end-gas there are three stages to be discerned when detonative combustion occurs: incubation, pre-reactions, combustion. Chemical detonation depends upon: fuel/air mixture, octane number, anti-knock agents, temperature and surface conditions of the combustion chamber walls, and the speed of the engine.

If the engine runs very slowly detonation may occur. This may be explained by considering that there is sufficient time so that stage three may be reached in the end-gas. If on the other hand, the engine runs very fast, temperatures in the combustion chamber increase in such a way that the walls may cause self-ignition of the end-gas before the primary flame front has proceeded through it. It is possible that, after the stage of self-ignition in the end-gas is reached, physical detonation is also present. Further experiments in bombs indicate that self-ignition may occur in the end-gas.

Hence, it is concluded that the pre-stages of the two phenomena of physical and chemical detonation develop simultaneously. Each has its own history. Which critical point will be reached first depends upon the circumstances and upon what kind of detonation will occur primarily.

WELDED CONSTRUCTION SAVES MATERIAL

By Ing. Paul Feldman. (From *Werkstatt und Betrieb*, Vol. 73, No. 4, April, 1940, pp. 79-80).

With the development of direct current arc-welding a new field opened up for machine constructions, more independent from casting. At the same time saving in material was achieved, which amounts to about 50%.

In the machine tool industry the employment of welded constructions is not widely enough adopted, although it is possible, now-a-days, to construct welded machine tools and machine tool parts. By arranging for suitably designed steel constructions the following improvements may be achieved:

(1) A possibility of rapid change in the design to keep step with technical advance and requirements.

(2) Reduction in the weight of the raw material.

(3) Hence a reduction in cost.

Welded constructions may be designed to have the same strength and elasticity as the heavier type cast machines. Earlier experiments to construct welded machines proved to be a failure, which, however, can be contributed to the fact that the old design of the machines was retained.

If the welded constructions are suitably designed all the above mentioned advantages can be achieved and the new type replaces the old one in every respect. The following conditions should be fulfilled in welded constructions :

(1) The welded seams must have the same strength, elasticity, heat resistance and coefficiency of expansion due to heat as the structural material used.

(2) Uniformly strong seams must be obtained, which must be carefully checked, and not be left to the skill of the labourer.

(3) The welding must be able to withstand and transmit great forces without any change in shape.

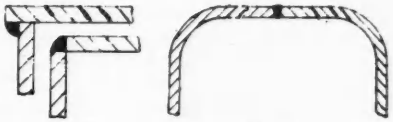


Fig. 1a. Fig. 1b.

(4) The natural frequency of the complete piece must be high, and resulting vibrations should be damped out.

All these conditions can be satisfied with a proper design. It was also found that the natural frequency of welded machines had a high value, which was very important, especially in connection with grinding and polishing machines.

In the earlier type of welded constructions welding took place as shown in Fig. 1a, along the corners. In newer design this has been changed, as shown in Fig. 1b, resulting in smaller dimensions, further saving in material, also less number of welded seams, smaller cross section, and more suitable location of the seams, i.e. displaced from points of max. loading.

PIEZO-ELECTRIC MEASURING SETS

By DR.-ING. P. K. HERMANN. (From *AEG-Mitteilungen*, No. 12, December, 1939, pp. 497-502).

THE conversion of mechanical into electrical energy, and vice versa, by means of the piezo-electric effect has been known for 100 years. In many crystals such as turmalin, cane sugar, quartz and sodium-potassium tartrate, mechanical tension causes a dielectric displacement, viz. polarisation, which is proportional to the tension and makes a definite angle with it and with the main axes of the crystal. The usefully converted energy is only a very small proportion of the total energy content of the state. In the case of quartz it is only 1%. Nevertheless, appreciable energy conversion can be effected by means of an oscillating quartz for " ultra sound generation." This is done by the powerless generation of high mechanical alternating tensions, and by the choice of very high resonance frequencies, so that even a small energy conversion per cycle gives a considerable total.

This article deals with the measurement of minute electrical energy, piezo-electrically produced by mechanical forces. The two crystals most widely used for this purpose are quartz and sodium-potassium tartrate. The former shows high mechanical strength, independence from temperature and invariability of its piezo-constants ; the latter shows an electric hysteresis of its dielectric constants and its piezo-constants depend considerably on temperature. Thus, quartz is more suitable for the indication of pressure and shock from explosion and combustion with its high demand on mechanical strength and its rapid changes of temperature and pressure. The demands made on indicators for combustion engines are discussed in detail, and several forms of indicators, such as mechanical, mechanical-electrical and electrical types are briefly described.

In the piezo-electric indicator the pressure in the combustion chamber is applied to a diaphragm and communicated to a quartz under pressure. The electrical charge pro-

duced on the crystal gives rise to a potential difference proportional to the pressure change and inversely proportional to the total capacitance of the circuit. The potential difference so obtained is applied to the deflecting plates of an oscillograph. The advantages of this type of indicator are:

(1) High natural frequency up to 30-50 kilocycles per second.

(2) Good sensitivity to shocks.

(3) Independence of temperature up to 300° C.

The application of a constant pressure and watercooling, necessary to maintain independence of temperature, present certain difficulties. Watercooled indicators are of larger mass and dimensions than the aircooled types, but still have a sufficiently high natural frequency of 30 kilocycles per second. The indicators are fitted with an ignition plug screw, the effective diaphragm area being 4 cm^2. Various forms of indicators are shown which can be used for low-pressure diagrams and for the pressure indication in suction, injection and exhaust pipes.

The charge on the indicator must be measured statically to avoid any possible discharge. A special amplifier is described in detail which enables a deflection of 15 mm. per atmosphere to be obtained on the oscillograph screen. The time constant of the whole circuit becomes 10-15 minutes, a time long enough for electrostatic measurements to be taken. A two-ray oscillograph and amplifier for simultaneous pressure measurements at two points and representation on one screen is also shown.

The importance of providing a proper time base which will give distances along the abscissa proportional to the crank angle is emphasised and two systems are described. In one of these two alternating voltages are set up, proportional to the sine of the crank angle and the sine of twice the crank angle respectively, giving the first two terms of the Fourier Series which represents the piston motion as a function of the crank angle. The superposition of these two voltages provides a very accurate time base. A simpler form utilises only the fundamental of the Series.

Finally, sodium-potassium tartrate indicators are dealt with. These are very sensitive to shocks, vibrations, accelerations, etc., and are suitable for direct connection to an oscillograph without previous amplification. Using a starter battery they have been applied to pressure measurements in motor cars and aeroplanes.

INVESTIGATION OF THE CAUSES OF GRAIN-BOUNDARY CORROSION IN HARDENED ALLOYS, OF THE AL-CU-MG TYPE

By M. Bosshard. (From *Schweizer Archiv*, Vol. 6, No. 10, October, 1940, pp. 265-279, continued from "The Engineers' Digest," Vol. II, No. 1, p. 40).

Table VII.

Thickness of sheet metal	Precooling in secs.	Time of corrosion in salt spray bath 0 month Tensile strength	0 month % Elong.	1½ months Tensile strength	1½ months % Elong.
0.5	1-3	45.3	20.5	35.0	4.5
1.0	1-3	45.3	22.2	42.2	10.0
2.0	1-3	44.2	20.0	43.3	15.3
3.0	1-3	44.7	20.1	44.6	15.4
5.0	1-3	44.1	19.4	43.5	16.1
0.5	40	44.5	18.0	24.9	1.3
1.0	40	44.6	18.8	34.5	4.9
2.0	40	43.9	19.2	40.0	9.3
3.0	40	44.2	19.4	42.0	10.5
5.0	40	43.8	19.0	42.9	16.3

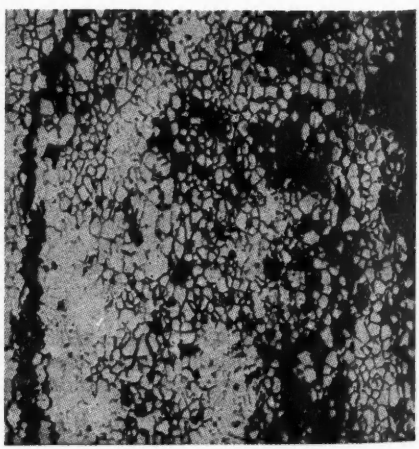


Fig. 7.

Magnification 60x, 1 mm. Avional Z sheet metal, heat treatment and corrosion as in Fig. 3, precooling 120 sec.

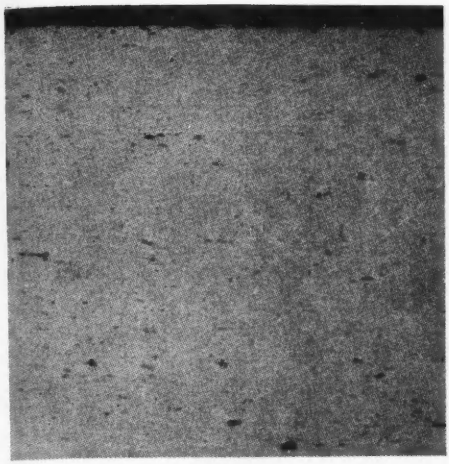


Fig. 9.
Magnification 150x., 1 mm. Avional D sheet metal. Heated for 30 minutes in salt bath at 510° C., pre-cooling 2 sec., quenched in water at 4° C., corrosion in acidic salt bath : 3 days.

Influence of Individual and Batch Heat Treatment.

This, too, has considerable influence on the resistance to corrosion. Avional D sheet alloys of 20 mm. width and 0.5 to 1 mm. thickness were packed in 5 mm. diam. bundles and were heat treated in air, pre-cooled for 20 to 40 secs., quenched at room temperature. On examination, after corroding the samples in acidic salt solution, intercrystalline corrosion could only be detected on the 0.5 mm. thick samples. Individual treatment would have caused, no doubt, intercrystalline corrosion on all samples.

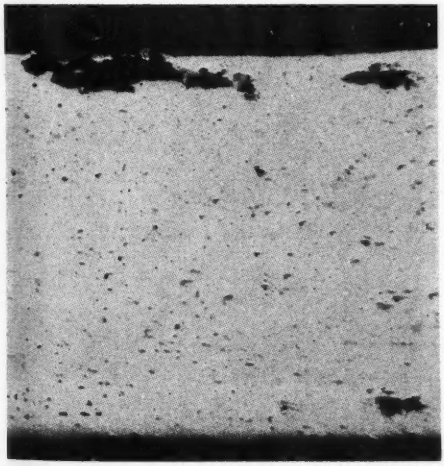


Fig. 10.
Magnification 60x., 1 mm. Avional D sheet metal. Heat treatment and corrosion as in Fig. 9, quenched in water at 20° C.

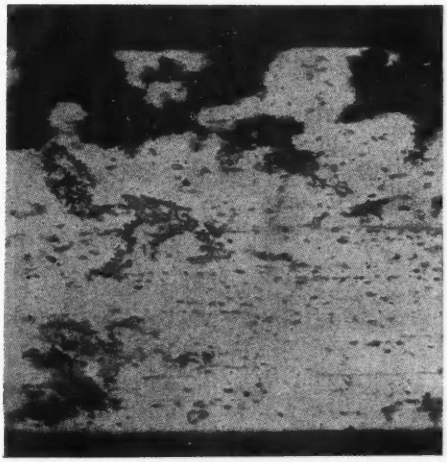


Fig. 11.
Magnification 60x., 1 mm. Avional D sheet metal. Heat treatment and corrosion as in Fig. 9, quenched in water at 50° C.

Fig. 12.
Magnification 60x. Avional D sheet metal. Heat treatment and corrosion as in Fig. 9, quenched in water at 100° C.

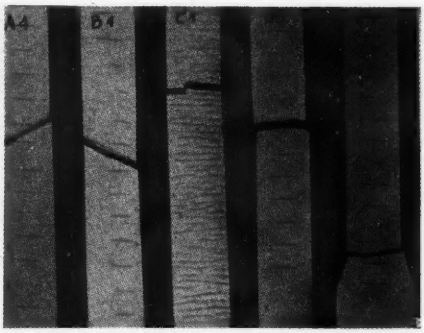


Fig. 8.

Experiments with larger samples gave different results. After corrosion, dark spots appeared on the middle of the samples, which were found to be spots of very strong intercrystalline corrosion (Figs. 17, 18, and 19). Further experiments were carried out with 1 mm. thick Avional D metal:

A sheet metal plate was divided up into thirteen strips and marked A-N. The first ten strips were heat treated when tied up in a bundle as before, the last three, however, were kept separate by a network. The heat treatment at 510°-515° C in salt bath for 30 minutes, was followed by quenching in water at about

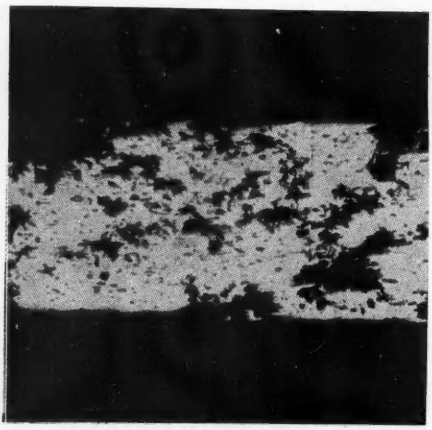


Fig. 13.

Magnification 60x., 0.5 mm. Avional Z sheet metal. Heated for 30 min. in salt bath at 490° C., precooling 2 sec., quenched in water at 20° C., corrosion in acidic salt bath : 3 days.

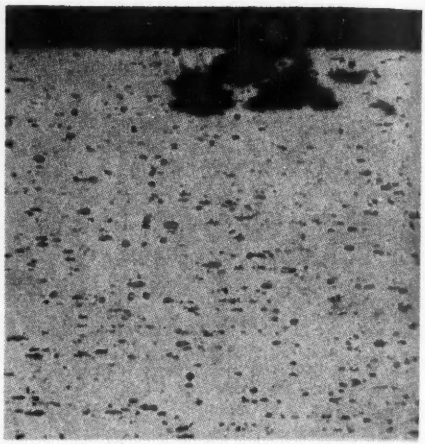


Fig. 14.

Magnification 60x., 5 mm. Avional Z sheet metal. Heat treatment, pre-cooling and corrosion as in Fig. 13.

15° C (pre-cooling for two to four secs.), and the samples were then allowed to stand for ten days at 20° C. Metal strips, 500 × 500 mm. marked from O to T were heat treated in air, those from O to S in a batch, and T separately. Heat treatment was as before.

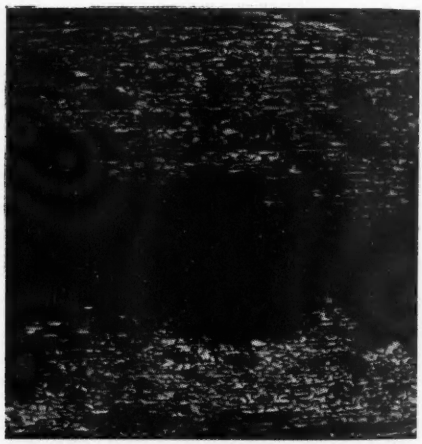


Fig. 15.

Magnification 60x., 1 mm. Avional Z sheet metal. Heated for 30 min. in salt bath at 490° C., precooling 40 sec., quenched in water at 20° C., corrosion in acidic salt bath : 3 days.

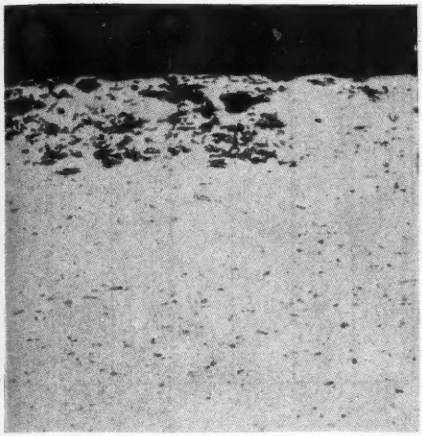


Fig. 16.
Magnification 60x., 3 mm. Avional Z sheet metal. Heat treatment, pre-cooling and corrosion as in Fig. 15.

Finally the samples were cut into 210 × 22 mm. strips and numbered, those treated in the salt bath 1-7, and those in the air bath

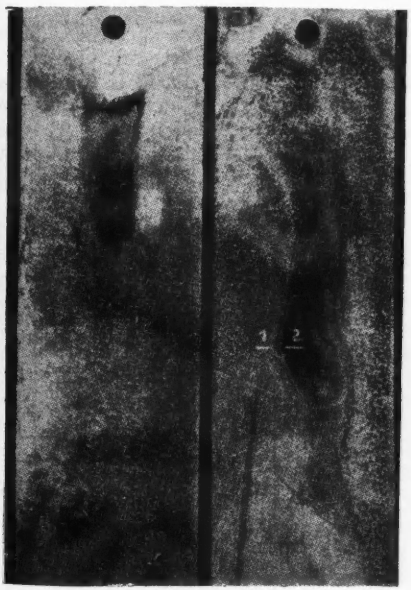


Fig. 17.
Surface of 1 mm. Avional D sheet metal. Heat treatment in bundles.

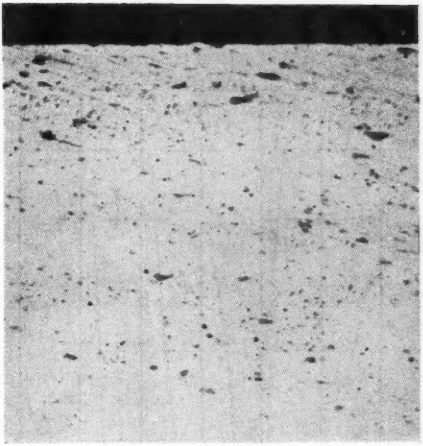


Fig. 18.
Magnification 150x. Slice at point 1 in Fig. 17.

1-30. Results of the examination of the physical properties are shown in Figs. a to h.

It can be concluded from these figures, that heat treatment in a batch causes a great dispersion of the strength and percentage elongation properties of the metal. The dispersion is greater when heat treatment in the salt bath takes place. The microscopic examination showed that fracture occurred

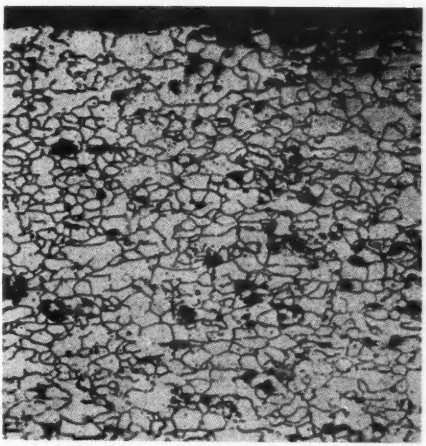
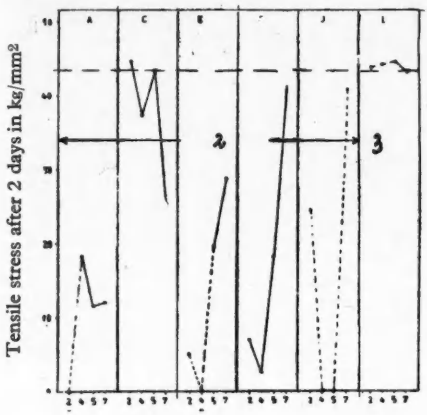


Fig. 19.
Magnification 150x. Slice at point 2 in Fig. 17.

Fig. a.

Corrosion of hardened Avional sheet metals in n/l salt bath+0.5% acid. Heat treatment in salt bath.



always at sections where intercrystalline corrosion was the strongest. In case of batch treatment, the quenching medium could not penetrate spontaneously and uniformly between the sheet metals, and this was equivalent in result to a prolongation of the pre-cooling period. Batch treatment in salt bath produced a salt scale on the metal surfaces, and irregularities became thus more eminent. On the other hand, in case of individual treatment, the salt bath forms a salt coating on the metals, which counteracts the dangerous effect of pre-

Fig. b.

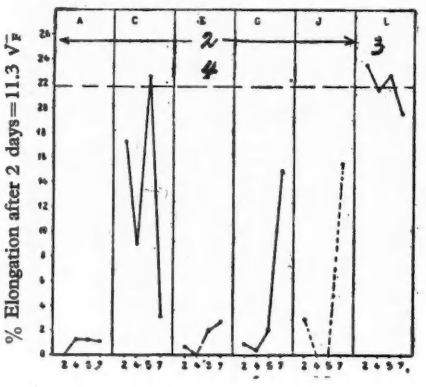
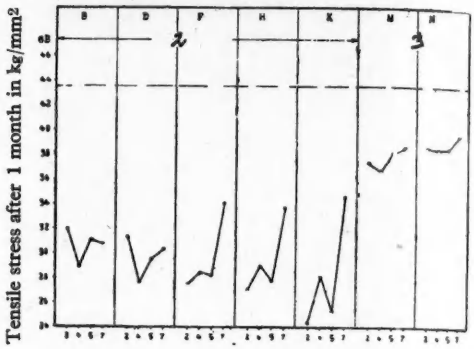


Fig. c.

Corrosion of Avional sheet metals in salt spray bath.

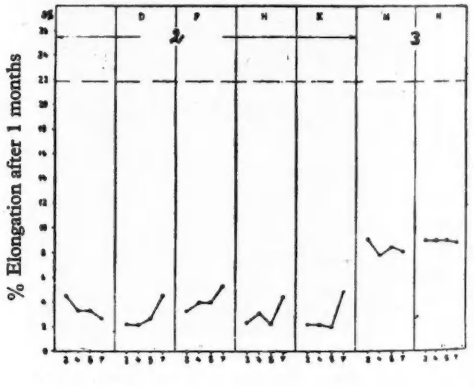


cooling. Hence, quenching in a salt bath can only be applied to individual pieces and not when they are fastened together into bundles.

Influence of the Constituents of the Alloys.

Experiments with Avional alloys of various composition showed that alloys with approximately 4% Cu in the absence of Mg, Si and Fe have the least tendency to corrode. Addition of Mg does not affect this greatly, but addition of Si and Fe decreases considerably the resistance to corrosion. This undesired effect of Si and Fe seems, however, to be somewhat reduced by the simultaneous addition of Mg.

Fig. d.



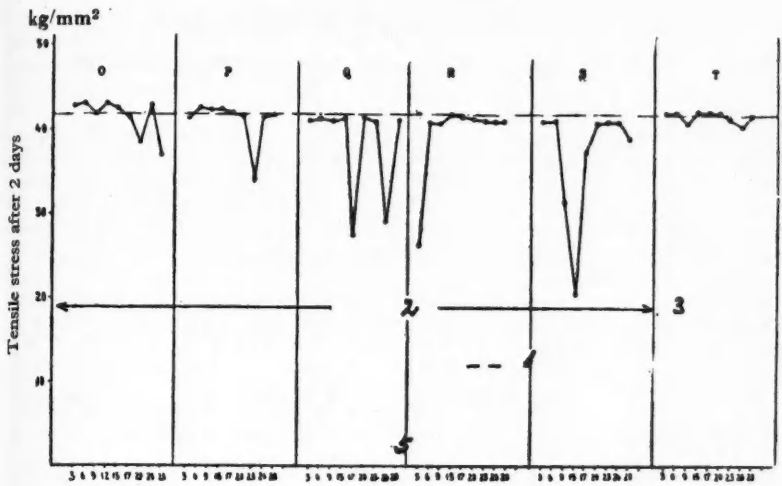


Fig. e.

Heat treatment in air bath, corrosion as in Fig. a.

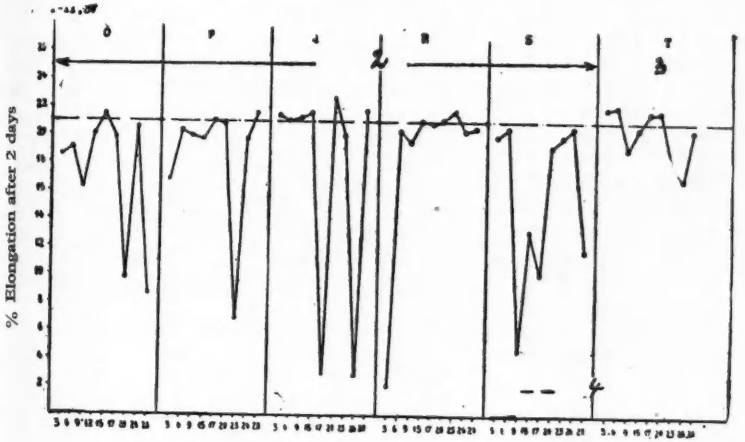


Fig. f

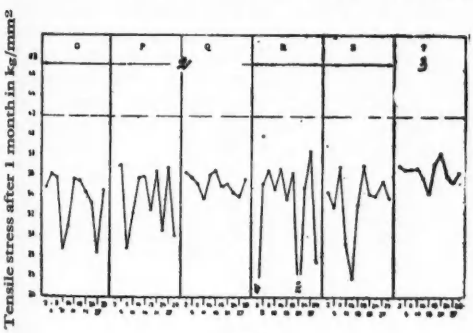


Fig. g.

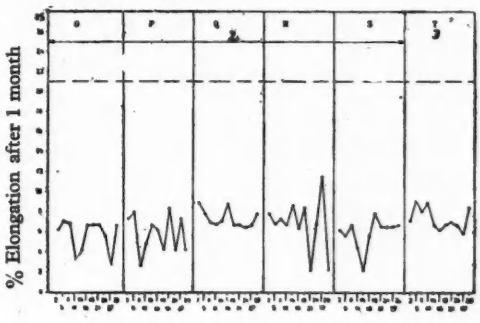


Fig. h.

THE SHAPE OF THROAT OF SCREW TAPS

By FRITZ MATTHEES. (From *Maschinenbau*, Vol. 19, No. 3, March, 1940, pp. 107-108).

THE influence of throat angle and of relief grinding on the output of tools is far greater than is usually expected. The type and amount of relief grinding which is necessary is fixed by practical research for standard types of screw taps. Difficulties are, however, experienced if the flanks of the threads are to be finished very accurately. In case of hand finishing the accuracy depends on the skill of the workman, and with machine relief grinding, either the proper adjusting elements or the possibility of adjusting the elements on the machine are not always available.

In general, more relief grinding is necessary if the throat angle is large, or the throat is short, or there are few turns only per unit length compared with a small throat angle, long throat, and many turns per unit length respectively. Fig. 1 shows the throat of a screw tap. Such a screw tap, if fitted with chip grooves, would jam, hence the necessity for relief grinding. This depends on α the pitch angle of the throat, and β the "free angle." The latter is the angle included between the line of screw tap pitch and the line of pitch of relief grinding. Its magnitude lies usually between 30′ and 3°.

Incorrect relief grinding, irrespective of whether too much or too little relief grinding takes place, always results in excessively large flanks. Figs. 2 and 3 show the result of incorrect relief grinding. It can be seen that too small relief grinding causes greater faults than too great.

These faults are more prominent if the screw tap is inaccurately guided. This can be avoided by using machines with guided feed, but in this case the relief grinding must under no condition be too small, otherwise the load on the machine becomes excessive.

The following table can be used for a quick determination of the relief grinding elements :

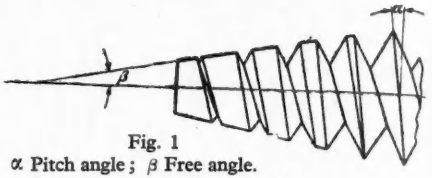


Fig. 1
α Pitch angle ; β Free angle.

Fig. 2
Fault in thread due to too great relief grinding.

Fig. 3
Fault in thread due to too small relief grinding.

It is essential that the screw tap shall have sufficient self guidance, and the cutting pressure counteracting the self guidance, must be kept at a low value. The self guidance must not be excessive and exert a pressure on the flanks.

It is advisable to use long throat with little relief grinding. If screw taps with sharply cut edges are used, the taps are withdrawn, tapering towards the throat, and hence a second cutting takes place during this movement. Usually, however, the flanks become rapidly blunt, and hence useless.

Variable relief grinding has been adopted lately, for which purpose a special type of screw tap had to be designed. Relief grinding is small at the beginning of cutting, and is gradually increasing towards the guiding shaft. On the guiding shaft it remains at a steady value. If a screw tap with short throat is used, the flanks are rounded, and at the beginning of the throat the relief grinding part is cut away (Fig. 4). From here on relief grinding is increasing gradually, and reaches the maximum value at the end of the throat (Fig. 5).

Throat angle	.. 19°	11° 30′	8°	5°	2° 40′	1° 20′	1°	40′
Relief grinding for 1 rev., 1 mm. incr.	..0,35	0,2	0,14	0,087	0,046	0,023	0,017	0,012

Free angle	3°	2° 30′	2°	1° 30′	1°	30′
Relief grinding for 1 rev., 1 mm. Fl. Diam.	0,164	0,137	0,110	0,082	0,054	0,027

Screw taps with long throats are frequently produced with flanks relief ground. The longer the throat, the later it acquires a satisfactory self guidance. The friction of the flanks becomes large at places where the cutting pressure is large and the surface of contact is small. Thus unnecessary overcutting is avoided at the beginning of the throat. At points where self guidance becomes sufficiently large, the cutting pressure is small or zero, i.e., at the end of the throat and along the guiding shaft the relief grinding is not too much, and hence overheating is avoided.

Such working can be performed with most types of throat cutting machines, and only small alterations are necessary to be performed.

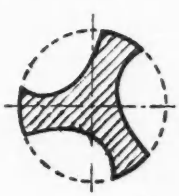


Fig. 4
Beginning of throat with relief grinding part cut away.

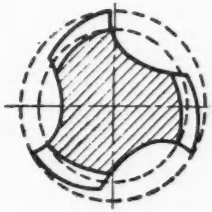


Fig. 5
End of throat with full relief grinding.

FATIGUE STRENGTH OF DIFFERENT TYPES OF RIVETING

By E. HOTTENROTT. (From *Luftfahrtforschung*, Vol. 17, No. 8, August 20th, 1940, pp. 247-250).

FOR the purpose of investigation single row, single shear riveting was used. With a sheet thickness of 1 mm., 3 mm. rivet diameter, rivet hole diameter 3.1 mm., and 20 mm. pitch, the ratio of tensile stress in the sheet, shear stress in the rivet and bearing strength is:

$$f_t : f_s : f_b = 1 : 2.24 : 5.45.$$

The test sample is shown in Fig. 1. The sheet metal and the fish plates are duralumin plated. The measured strength figures are:

Yield stress f_y .. .. = 30 to 34 kg/mm²
Ultimate stress f_{max} .. = 42 to 45 kg/mm²
Percentage elongation d = 19 to 21%

6 different types of riveting (A to F, Fig. 2) were tested. A has a mushroom head, and recessed plate and stiffener flanges. Similarly B, with the flat head of rivet inside. C has a head-flush which is counterbored to full sheet thickness. D has a round-head rivet. E and F have a 3 mm. thick extended stiffener,

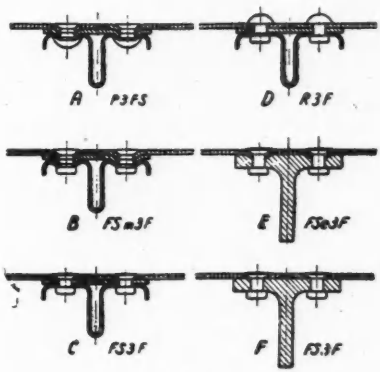


Fig. 2

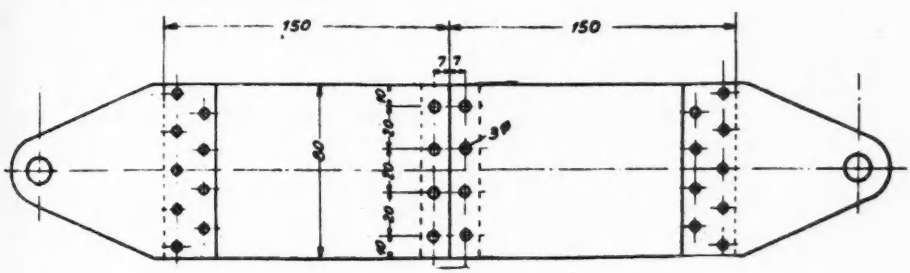


Fig. 1

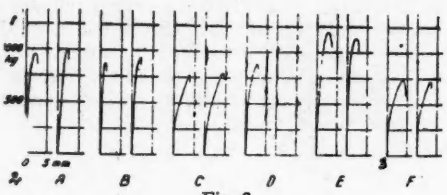


Fig. 3

1 Load; 2 Riveting; 3 Elongation.

instead of the weak stiffener and plate. The type of riveting is clear from the figures. The shear stress of the rivets used is 27 kg/mm².

Two sets were tested from each rivet type. The loads and elongations were measured in each case as shown in Fig. 3. The breaking loads and shear stresses at fracture are tabulated:

Riveting	A	B	C	D	E	F
Breaking load per Rivet in kg.	243	229	197	227	293	186
Nominal shear stress in kg/mm²	32.3	30.4	26.2	30.2	38.9	24.7
Angle of shear⁰	20	20	0-10	0	20-35	0

It can be seen that a maximum breaking load is obtained in case of E. Rivets A, B, and D show similar results. Least values were obtained with C and F, when no recessed sheet was used. The higher values of the breaking load in the other cases may be due partly to the larger cross section resisting shear (the rivet holes are enlarged due to recessing and are filled up with the rivet material), and partly to a component of the force along the rivet-

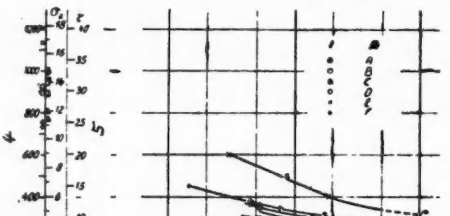


Fig. 5

1 Sign; 2 Riveting; 3 Various loading; 4 Breaking load, upper limit, kg; 5 Nominal shear stress kg/mm²

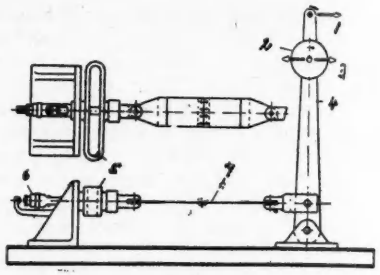


Fig. 4

axis. As a result of the latter, fracture takes place at an angle (angle of shear) to the sheet surface.

Appreciable strains were only found in case of A, B, D, and E, when the load was increased to 700 kg. Permanent set was reached in case of C and F already at a load of about 250 kg. Measurements on the unfractured side of the samples showed that the sheet metal was shifted towards the rivet by an amount 0.7 to 1.1 mm., out of which 0.5 to 0.7 mm. was due to enlargement of the rivet hole and the rest due to deformation of the rivet.

An oscillating lever-mechanism was employed for fatigue tests (Fig. 4). The speed of the mechanism was near to resonance and was about 1000-1200 r.p.m. The upper and lower limits of loading could be read off from a spring scale. The lower load limit was kept at a constant value, 30 kg. throughout the experiment, while the upper limit was varied but, of course, being kept constant within one test up to fracture.

Fig. 5 shows the frequency for various loadings (Wöhler Curves). The statical breaking loads are also shown on the same graph. The figures given are nominal values.

Breaking loads for the frequency 2×10^6 are tabulated:

Riveting	A	B	C	D	E	F
Upper limit of load for 1 Rivet in kg.	70	60	55	62.5	97.5	75
Nominal stress in sheet kg/mm²	4.1	3.5	3.2	3.7	5.8	4.4
Place of fracture: Fish plate F Sheet skin C	F	F	C	F	C	C

The maximum value obtained with E is about 80% greater than that in case of C; A, B, and D show about similar results, the load varying from 4.1 to 3.5 kg/mm². In case of C, E, and F the sheet skin fractured first, the load varying between 3.2 to 5.8 kg/mm². Note that fracture took place only either in the fish plate or in the sheet. When rivet type F was tested with 6.7 kg/mm² max. load, the fracture started in both the sheet and rivet simultaneously, after 0.145×10^6 repetitions.

Typical fractures are shown in Figs. 6 and 7. It can be seen that with A and B, fracturing did not take place along the centre line of the rivets, i.e., the weakest section, but started at various points near the recess of the skin. Similarly with D, fractures started near the rivet holes.

The deformation of the rivets and rivet holes was negligible in case of A, B, and E. It was more in case of D and was excessive in case of C and F.

Experiments carried out with riveting type F, showed a elongation of about 1.2 mm. at a frequency from 0 to 25000, after which there was no increase until fracture occurred. This behaviour is probably due to the enlargement of the rivet hole (80%) and the deformation of the rivet (20%).

Results.

From calculations, taking $f_s = 26$ kg/mm², the maximum static load for one rivet was found to be 195 kg. The measured values of the ultimate loads and the fatigue loads for the frequency 2×10^6 are given in the following table, and are expressed as percentage values of the calculated value.

Riveting	A	B	C	D	E	F
Breaking load per rivet % (a)	125	117	101	116	150	96
2×10^6 limit per rivet % (b)	36	31	28	32	50	38
Ratio : a/b	0.29	0.26	0.28	0.27	0.33	0.40

It can be seen that the highest and lowest values were obtained with the extended stiffener (E and F). Also the maximum fatigue value was obtained with E.

The following points should be noted:

(1) With recessed sheets an enlargement of the area transmitting the force, and hence smaller local loads are obtained.

(2) With recessed riveting and with extended stiffeners, a better guiding of the rivet is achieved.

(3) With recessed sheets fracture starts at the transition point from the flush rivet to the recessed part.

(4) With counter bored sheets permanent deformation starts already when the load is small. This allows relative movement of the parts, resulting in reduction of the fatigue strength.

ELIMINATION OF BELT STATIC

By W. F. SCHAPHORST. (From *News Edition, American Chemical Society*, Vol. 18, No. 8, 25th April, 1940, p. 355).

IT is possible to prevent the formation of static electricity in belts by making the belt a good conductor of electricity, or by using a belt of material that is a good conductor.

Powder manufacturing companies are exceedingly careful and are successful in preventing the formation of static. Research engineers of one large powder manufacturing company found that a graphite solution is very effective as a preventative of static. Another powder manufacturing company uses 50 per cent glycerol and 50 per cent water. This solution is satisfactory so long as its application is continued and the belt is maintained in a moist condition. Static electricity is generated by belt slippage and by continuous making and breaking of contact between the belt and the pulleys.

When combs are used, they should be placed at the midpoint of the belt.

By using a high-grade, plyable, high-friction belt, which will not slip, which has good conductivity and which is smooth on both sides, serious static troubles will not be experienced.

It is preferable to use a high quality two-ply belt because both sides of double belts are always smooth.

SPOT TEST FOR THICKNESS OF CHROMIUM COATINGS

(From *Technical News Bulletin of the National Bureau of Standards, Washington*, No. 279, July, 1940, p. 57).

CHROMIUM coatings over nickel deposits on such articles as automobile parts and plumbing fixtures are too thin (about 0.00002 in.) to be measured by customary methods. The spot test is usually used, in which a measurement is made of the time required for one drop of concentrated hydrochloric acid to dissolve the coating. This method, with temperature corrections, is now prescribed in tentative specifications adopted by the American Electroplaters' Society and the American Society for Testing Materials.

It can be shown that it is necessary to control closely not only the temperature, but also the concentration of the hydrochloric acid. The use of 11.2 N HCL having a specific gravity at 60°/60° F. of 1.180 is recommended, and a temperature-correction curve for that strength of acid has been plotted. With these precautions, the results are accurate to about 10%.

PATENTS AND INVENTIONS

Belt Drive for Individual Electric Motor Drive for Machine Tools. (DRP 674 556, by J. Wüst). The attachment of the motor to the machine is such that a short belt drive is obtained. This is usually achieved by pivoting the tilting motor arrangement to the machine by means of a swinging arm. During the drive the belt is kept tight by the weight of the motor. To avoid frequent switching "in" and "off" of the motor, the machine is started and stopped by raising or lowering the motor. A catch is also provided to keep the motor in the "off" position.

The electric motor (1) can swing round the arm (3) at the pivot (4) fixed to the machine (5). When the motor is driving the machine the belt is tightened by the weight of the motor. The handle (8) serves to lift the motor and to slaken the belt so that the driving pulley (2) can be passed below the belt. The handle is operated by a pull-bar (9). The catch arm (10) is fixed to the arm (3). If the handle (8) is pulled in order to stop the machine the belt becomes slack, and the brake (11) presses against the driving pulley (12), and stops the machine. In this position (10) is past the catch (13). On releasing the handle the catch (13) will fix the arm (1) in the position where the machine is at standstill. Lifting the handle (8) the machine can be started again.

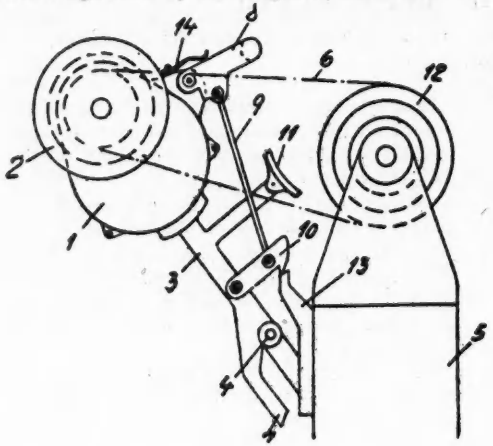


Fig. 1

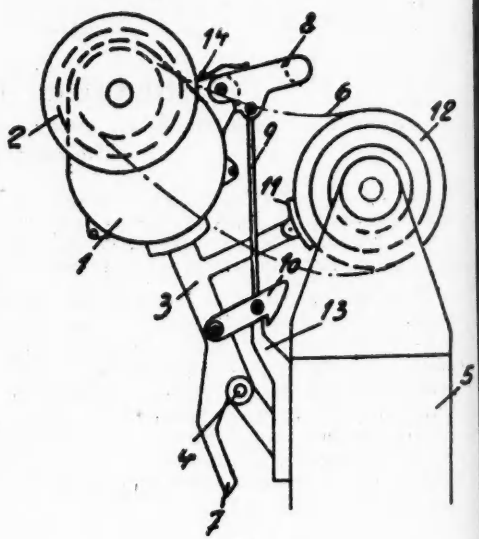


Fig. 2

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